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ABSTRACT

This document presents the hearing of the Subcommittee on Research, Committee on Science, House of Representatives, held May 2, 2001. The content of the hearing focuses on the educational improvement of science education at the K-12 level and includes the following speakers' statements: (1) Representative Eddie Bernice Johnson, Ranking Minority Member, Subcommittee on Research, Committee on Science, U.S. House of Representatives; (2) Education Department Chair, Phil Sadler, Science Education Department, Director Harvard-Smithsonian Center for Astrophysics; (3) Eugene Carl Schaffer, Education Department, Chair, University of Maryland, Baltimore County; (4) David Garner, Urban Systemic Program, Director, Oklahoma City Schools, Curriculum and Instruction Department; and (5) Carl Parravano, Merck Institute for Science, Director. (YDS)

IMPROVING MATH AND SCIENCE EDUCATION SO THAT NO CHILD IS LEFT BEHIND

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH

COMMITTEE ON SCIENCE

HOUSE OF REPRESENTATIVES

ONE HUNDRED SEVENTH CONGRESS

FIRST SESSION

MAY 2, 2001

Serial No. 107–27

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IMPROVING MATH AND SCIENCE EDUCATION SO THAT NO CHILD IS LEFT BEHIND

MAY 2, 2001

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH,
COMMITTEE ON SCIENCE,
Washington, DC.

The Subcommittee met, pursuant to call, at 2:10 p.m., in the Rayburn House Office Building, Hon. Nick Smith [Chairman of the Subcommittee] presiding.

Chairman SMITH. Research will come to order. Today the House Science Subcommittee on Research meets to discuss the improvement of K through 12 math and science education and some possible roles the National Science Foundation might play in that effort.

The most recent results from the Trends in Mathematics and Science Study, the TIMSS, show that our efforts to improve U.S. math and science education have had some successes but overall have been ineffective in raising U.S. performance from the middle-of-the-pack position.

There are some particular successes that I would also like to be allowed to mention, and one of those is Michigan, which achieved the top U.S. state scores in both math and science, and there truly are many bright spots on the rather dim U.S. education horizon in this area but there is no question that we need to work harder to make the top performers the norm and not the exception.

The President's plan to improve education, No Child Left Behind, certainly the math and science partnership initiative, highlights the importance of partnerships between K through 12 schools and institutions of higher education in leading the math and science education reform effort. As part of that plan the President charged the National Science Foundation with the responsibility of implementing and managing a Math and Science Partnership Initiative. Today we will examine the role of various kinds of partnerships in education reform by hearing from those that have experience in this area and can be of great help as we try to formulate how we best move ahead in this venture to improve math and science education.

Our witnesses today are among the nation leaders in math and science education reform. They represent a diversity of stakeholders and participants including K through 12 schools, institutions of higher education, and industry leaders who have made a significant local impact and who have established national models

of excellence in science and mathematics education reform. While each of their programs is unique they are all firmly grounded in the belief that successful reform is dependent upon strong partnerships that engage and enable researchers and practitioners of science, mathematics, and education.

And I might say there is some evidence that teachers with more training in math and science than required for their teaching certificate are often more effective in teaching their own students math and science. The Philadelphia Collaborative for Excellence in Teacher Preparation, for example, demonstrated that the students of these teachers achieved higher schools on standardized testing than students taught by teachers who graduated from traditional teacher training programs.

Today I am interested in hearing about our witnesses' efforts in education reform. I hope you as our witnesses will provide us with details and directions regarding some of the key elements pivotal to the successes you have seen and the danger spots that we might encounter. Through our exploration in these efforts perhaps we will better understand what works and how best to make it more broadly applicable across the United States.

I would like to also point out that the Subcommittee will meet again next week to examine education research in depth, an issue related to the topic that we will also discuss today.

I want to thank our witnesses for appearing with us today, and I look forward to your testimony, and the Chair would now—I intend to recognize the Ranking Member, Eddie Bernice Johnson, and then I will recognize the Chairman of our Committee for a statement, and then Dr. Ehlers, if you would like to make a short statement, and we will proceed as quickly as we can to not detract from the time we have with our witnesses. And with that I would turn it over to our Ranking Member for her statement.

[The prepared statement of Nick Smith follows:]

PREPARED STATEMENT OF CHAIRMAN NICK SMITH

Today the House Science Subcommittee on Research meets to discuss the improvement of K–12 math and science education and some possible roles the National Science Foundation might play in that effort.

The most recent results from the Trends in Mathematics and Science Study (TIMSS) show that our efforts to improve U.S. math and science education have had some successes, but overall have been ineffective in raising U.S. performance from its middle-of-the-pack position.

There are some successes that I would like to highlight, however, including my own state of Michigan, which achieved the top U.S. scores in both math and science. There truly are bright spots on the rather dim U.S. education horizon, but we need to work harder to make the top performers the norm and not the exception.

The President's plan to improve education, *No Child Left Behind,* highlights the importance of partnerships between K–12 schools and institutions of higher education in leading the math and science education reform effort. As part of that plan, the President charged NSF with the responsibility of developing, implementing, and managing a Math and Science Partnerships Initiative. Today we'll examine the role of various kinds of partnerships in education reform by hearing from those with experience using them.

Our witnesses today are among the nation's leaders in math and science education reform. They represent a diversity of stakeholders and participants including K–12 schools, institutions of higher education, and industry leaders who have made a significant local impact and who have established national models of excellence in science and mathematics education reform. While each of their programs is unique, they are all firmly grounded in the belief that successful reform is depend-

ent upon strong partnerships that engage and enable researchers and practitioners of science, mathematics and education.

I'm interested in hearing about our witnesses' efforts in education reform and hope they'll provide us with details and direction regarding some of the key elements pivotal to their success. Through our exploration of these efforts, perhaps we will better understand what works and how best to duplicate it.

I should also point out that the Subcommittee will meet again next week to examine education research in depth, an issue related to the topic we'll discuss today.

I want to thank the witnesses for appearing today, and I look forward to your testimony.

[Witness List and Hearing Charter follows:]

COMMITTEE ON SCIENCE

SUBCOMMITTEE ON RESEARCH

U.S. HOUSE OF REPRESENTATIVES

WASHINGTON, DC 20515

Hearing on

IMPROVING MATH AND SCIENCE EDUCATION SO THAT NO CHILD IS LEFT BEHIND

Wednesday, May 2, 2001

WITNESS LIST

Dr. Philip M. Sadler

Director, Science Education Department,

Harvard-Smithsonian Center for Astrophysics

Dr. Eugene Carl Schaffer

Chair, Education Department

University of Maryland, Baltimore County

Mr. David Garner

Director, Urban Systemic Program

Oklahoma City Schools

Curriculum and Instruction Department

Dr. Carl Parravano

Director, Merck Institute for Science Education

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HEARING CHARTER

SUBCOMMITTEE ON RESEARCH
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Improving Math and Science Education So That No Child Is Left Behind

WEDNESDAY, MAY 2, 2001
2:00 P.M.—4:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

I. Purpose

On Wednesday, May 2, 2001 at 2:00 p.m., the House Science Committee's Subcommittee on Research will hold a hearing on possible roles for the National Science Foundation in improving K–12 math and science education. Witnesses will comment on the role of institutions of higher education, private industry, and other organizations in working with State and local school systems to bring about positive change in the nation's K–12 classrooms.

II. Background

In his proposal for reforming K–12 education in the U.S., *No Child Left Behind,* President Bush laid out a comprehensive agenda for improving the nation's K–12 schools. Included in his package of proposed reforms was a call for partnerships between institutions of higher education and K–12 schools aimed at strengthening the quality of math and science instruction in elementary and secondary schools. Types of partnership activities addressed in *No Child Left Behind* included: making math and science curricula more rigorous, improving math and science professional development, attracting more math and science majors to teaching, and aligning high school math and science standards to foster college placement. In the President's initial budget request, *A Blueprint for New Beginnings,* President Bush charged the National Science Foundation with the responsibility for undertaking this initiative.

Math and Science education in the U.S.

The United States spends an estimated $120 billion a year on overall K–12 education, yet American students' performance on the latest round of the Third International Mathematics and Science Survey (TIMSS) shows that American students lag behind their international counterparts in both mathematics and science performance. Moreover, in the ten years since the first TIMSS study results were released, the significant attention directed toward science and mathematics education has not resulted in the expected improvement in student performance, nor has it led to a significant increase in the numbers of American students pursuing higher education degrees—and ultimately careers—in science, mathematics or engineering.

Several factors have been cited as contributing toward this national failure to lead our children toward excellence in science and mathematics. These include:

- too many teachers teaching out of field;
- inadequate teacher preparation in the areas of science and mathematics;
- too few schools with challenging math and science curricula and textbooks;
- too few students taking advantage of advanced coursework; and
- a lack of connection current understanding into how students learn and classroom practices;

Partnerships between colleges and universities and K–12 school systems have a role in addressing each of these shortcomings.

Interactions between universities and K–12 schools in current NSF programs

The National Science Foundation will spend $273 million on K–12 grade math and science education, not including funds for informal science education or programs supported by H1–B visa fees, in FY 2001. Of the variety of K–12 math and science programs the NSF funds, a higher number involve interactions between K–12 local and state school systems and institutions of higher education. While several

of these programs have attempted to foster and facilitate partnerships between institutions of higher education and local schools, each has had either a strong K–12 emphasis or a strong higher education emphasis, and thus none accomplished true partnership of the magnitude emphasized by the President's plan.

One example of an NSF program that has involved, in many cases, partnerships between universities and K–12 school systems is the Systemic Initiatives program. This program seeks to improve K–12 math and science education by intervention at many different levels, from the development and use of standards, to curricula improvement and enhanced teacher preparation and professional development. Similarly, in keeping with the emphasis on large-scale reform—systemic change—these efforts generally aim to involve as many of the various participants in the education system as possible, including teachers, school principals, superintendents, and other education policymakers at all levels of state and local government. Grants under the Systemic Initiative program have been given to a number of states, geographic regions, and various rural and urban areas. While not a requirement of the program, a number of these programs have incorporated institutions of higher education—colleges, including community colleges, and universities—into their activities.

While NSF's Systemic Initiatives program has been in existence for a number of years, other, more recent activities sponsored by NSF have continued to emphasize interactions between institutions of higher education and K–12 school systems in improving K–12 education. For example, NSF's Collaboratives for Excellence in Teacher Preparation (CETP) program, which will be phased out in FY 2002, was developed to award grants to institutions of higher education to aid in the preparation of future K–12 math and science teachers. Many of these programs were successful in engaging faculty from traditional math and science departments to engage in improved preparation of teachers and several of these programs led to statewide increases in math and science coursework requirements for teacher certification.

Other examples of NSF programs involving collaboration between institutions of higher education and K–12 school systems are NSF's Centers for Learning and Teaching, which aim to facilitate the development of comprehensive, research-based approaches to improving teaching and enhancing learning, and the Graduate Teaching Fellows, or GK–12, program, which supports the placement of science and math graduate students into K–12 classrooms to act as content resources for K–12 teachers.

Future targets of reform in K–12 math and science education

Education experts have suggested numerous targets for reform of K–12 math and science education, including:

- Interactions between institutions of higher education and K–12 school systems, especially those that draw on the expertise of mathematicians, scientists, and engineers. Roles colleges and universities might play in K–12 education are in the initial training as well as the ongoing professional development of K–12 teachers, the development of curricula and other materials available to teachers, the development of assessment tools for accurately measuring student mastery of content and cognitive skills, and the design and implementation of enrichment programs for K–12 students.
- K–12 math and science education programs initiated by industry, scientific research institutions, or professional societies. Industry has an enormous stake in the success of the United State's K–12 math and science programs, and can offer additional resources for K–12 science and math programs that is complementary to those provided by colleges and universities.
- Recruitment and training of additional K–12 math and science teachers, through programs that offer incentives to students majoring in science, math or engineering, and encouragement of institutions of higher education to develop high-quality programs that serve the unique needs of these future teachers.
- Education research, both research into how students learn—cognitive science—or large-scale assessments of particular teaching practices or curricula. The interaction between research and K–12 education is important in improving math and science education and will be explored in a future hearing.
- Providing easy access to educational materials and practices to K–12 math and science teachers.

III. Witnesses

The Subcommittee will hear from four witnesses with expertise in designing and implementing K–12 math and science education reform programs:

1. Dr. Phil Sadler, Director of the Science Education Department at the Harvard-Smithsonian Center for Astrophysics. As such, Dr. Sadler has had experience in running numerous parrtnerships aimed at improving math and science education from the higher education perspective. Dr. Sadler holds a joint appointment at the Harvard University Graduate School of Education, and is an F.W. Wright Lecturer on Navigation in the Harvard University Department of Astronomy.
2. Mr. David Garner, Executive Administrator of the Urban System Program, Oklahoma City Public Schools. Mr. Garner, a former middle school science teacher and coordinator of a comprehensive after school program for at-risk students, was a two-time winner of the Oklahoma City Public Schools Teacher of the Year award. He is now the Principal Investigator and primary researcher for the district's NSF Urban Systemic Program and has experience in partnerships with institutions of higher education, including those facilitated by the Urban System Initiative Award and the NSF-funded Oklahoma Teacher Education Collaborative.
3. Dr. Carlo Parravano, Director, Merck Institute for Science Education. Dr. Parravano, a former professor of physical chemistry at the State University of New York and a pioneer in the effort to link university and corporate researchers with K–12 teachers, joined Merck in 1992 to launch the Merck Institute for Science Education. The Institute considers teacher professional development central to its mission to nurture the sense of wonder in children and to develop teachers who can encourage enthusiasm for science and mathematics.
4. Dr. Eugene Shaffer, Chair of the Education Department at the University of Maryland, Baltimore County. Dr. Shaffer has a wealth of experience in working with K–12 schools to design programs that address the unique needs of specific schools or districts through teacher certification and teacher continuing education. The UMBC Department of Education awards no undergraduate degrees in education; rather, all students must first complete a baccalaureate degree in arts and sciences prior to enrolling in the teacher certification program. UMBC strongly recognizes the need to include math, science and engineering faculty in teacher preparation and teacher professional development and has developed strong ties with the traditional discipline departments to facilitate this work.

Questions

- What are the major barriers to full implementation that should be considered in developing new partnership programs? How can we ensure that partnerships meet the different needs of classroom teachers, school administrators, district administrators and policy makers?
- Scientists, engineers, and mathematicians are relatively new players in the world of K–12 education and their participation is often ad-hoc and largely unstructured. How does the participation of those individuals benefit K–12 partnerships and how can we encourage more practitioners of science, mathematics and engineering to get involved in K–12 education programs?
- How can the federal government provide incentives to encourage companies for whom education is neither the primary mission nor a source of revenue to invest corporate resources in educational programs?
- What programs would help in the national effort to recruit and retain more math and science teachers and that would encourage practicing mathematicians and scientists, in mid-career or post-retirement, to transition to careers in teaching?

Ms. JOHNSON. Thank you very much, Mr. Chairman. I am pleased to join you in welcoming our witnesses to today's hearing on exploring ways to improve K through 12 science and math education. I want to particularly call to attention to the title of the hearing, which emphasizes that we seek solutions and will result in improved academic performance for all students.

In the past concerns about science education were motivated largely by the goal of insuring a full pipeline of students moving toward careers in science and technology but we now see that technology infuses more and more aspects of our daily life. Clearly, all students need a basic grounding in science and math to function in an increasingly complex world and to lead fulfilling lives.

Most workplaces are becoming increasingly technological while our society is becoming increasingly diverse. We are running the risk of a widening gulf between those with training to thrive in this new work environment and those lacking the basic skills to qualify for high-tech workplace.

An important purpose of the hearing is to look at how to establish partnerships between the schools and institutions of higher learning to help bring about lasting improvements in student performance in science and math. We are also interested in encouraging partnerships between schools and industry with the same goal in mind. We hope as our witnesses today will be able to draw on your experience to assist us in understanding the most effective roles for the participants in these partnerships and the barriers to be overcome in making them work.

I have a strong interest in this topic because it directly relates to legislation I have proposed for the last few Congresses and reintroduced it yesterday. This bill is called the Mathematics and Science Proficiency Partnership Act.

The bill is targeted—is a target measure. It seeks to bring schools with large populations of economically-disadvantaged students together with businesses to improve science and math education and to recruit and support students in undergraduate education in science and technology fields.

The components of the partnerships will include support of the schools for teacher training, education materials and equipment, as well as establishment of college scholarships for promising students and on-job job site interns with industry.

The National Science Foundation will be authorized to award partnership grants where the awards will be based on how effectively the schools and businesses have forged their alliances and on the level of resources the private sector partners will provide.

Businesses will participate in partnerships by, and most importantly, setting up college scholarships for promising math and science students by establishing a job-site mentoring and intern programs and by donating computer software and hardware in participating schools.

Ways that schools will participate include providing innovation in-service training for their math and science teachers and informing their students of the career opportunities in science and technology.

And I will file the rest of this statement. We just completed in my hometown this weekend a Congressional Black Caucus Tech-

nology Summit where we reviewed much of this area and where in my area we have a great deal of participation with the private industry but we need more, and we need it across the country.

Thank you, Mr. Chairman.

[The prepared statement of Eddie Bernice Johnson follows:]

PREPARED STATEMENT OF THE HONORABLE EDDIE BERNICE JOHNSON

I am pleased to join the Chairman in welcoming our witnesses to today's hearing on exploring ways to improve K–12 science and math education. I want particularly to call attention to the title of the hearing, which emphasizes that we seek solutions that will result in improved academic performance for all students.

In the past, concerns about science education were motivated largely by the goal of ensuring a full pipeline of students moving toward careers in science and technology. But we now see that technology infuses more and more aspects of daily life. Clearly, all students need a basic grounding in science and math to function in an increasingly complex world and to lead fulfilling lives.

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The National Science Foundation will be authorized to award partnership grants, where the awards will be based on how effectively the schools and businesses have forged their alliances and on the level of resources the private sector partners will provide.

Businesses will participate in partnerships by, most importantly, setting up college scholarships for promising math and science students; by establishing job-site mentoring and internship programs; and by donating computer software and hardware to participating schools.

Ways that schools will participate include providing innovative in-service training for their math and science teachers, and informing their students of career opportunities in science and technology fields.

In order to assess the value of this pilot program, the legislation also directs NSF to conduct a longitudinal study of the students who participate in the partnership's scholarship program. This will determine the students' educational attainments and their success in entering careers in the fields of mathematics, science and information technology.

The nation must take advantage of the human resource potential of all our people if we are to succeed in the international economic competition of the 21st century. This will require that reform efforts in science and math education seek to engage and cultivate the interest of all children.

I believe my bill will help contribute to this goal. It will provide an unprecedented opportunity to redefine the federal role in K–12 education that establishes clear national priorities, provides incentives for change, disseminates best practices, and targets assistance effectively. I invite our witnesses to provide their views on the approach I have proposed. And, more generally, I encourage their suggestions and recommendations on the kinds of federal initiatives that will lead to improved science and math education in the schools.

In an age now driven by the relentless necessity of scientific and technological advancement, the current preparation that students in the United States receive in

mathematics and science is, in a word, unacceptable. Proficiency in mathematics and technology is necessary to prepare American students for participation in the 21st century and to guarantee that the United States' economy remains vibrant and competitive. Now is the time to set the stage for advancement in mathematics and science proficiency. The United States must expect more from our educators, businesses, and students.

I appreciate the attendance of our witnesses today, and I look forward to our discussion.

Chairman SMITH. Thank you, and our esteemed Chairman, Chairman Boehlert. Would you like to make a comment?

Mr. BOEHLERT. Thank you, Mr. Chairman. You know, of all the hearings taking place on the hill today in both the House and Senate none exceeds in importance this subject matter, improving science and math education. And to the credit of the President and this Administration there is a commitment to give this the priority attention it deserves.

We have already made significant progress. Initially people thought only in terms of the Department of Education and the Education and Work Force Committee when addressing this subject. They now recognize that this Committee intends to be a major player and a major contributor and that the National Science Foundation, for example, has a significant role to play.

So I want to commend you, Mr. Chairman, for the dedication of this Subcommittee, and I want to indicate to all the witnesses and anyone else paying attention to this subject that we are committed to improving, substantial improvement.

As you indicated the TIMSS study shows we are about average in science and math performance at the eighth grade level. That is not nearly good enough to sustain our preeminent position in the world economy.

So I thank you, I appreciate all of the witnesses serving as resources to this Committee, and I look forward to the product that you will produce for the Subcommittee and move it forward.

Chairman SMITH. Thank you, Mr. Chairman. Mr. Etheridge has indicated in the conservation of time he would make some extra comments during the questioning period. Mr. Ehlers, would you like to make a comment?

Mr. EHLERS. Very briefly. I share your pride in the fact that Michigan is ranked the highest in the TIMSS study in this country. That is the good news. The bad news is at that level it is roughly average compared to all the other countries of the—developed countries of the world. So even the best in this country is average compared to other countries.

That indicates we have a ways to go. This—I agree with the Chairman that this is a very important topic. I have devoted approximately 30 years of my life to trying to improve science and math education in K–12 while I was in the classroom as a teacher and professor, and I have devoted several years of my time here. I hope that we can soon do a good deal from this Congress to help improve math, science education in the United States. Thank you.

Chairman SMITH. I personally spent about 20 years trying to improve my personal test scores in math and science.

At this time I would like to introduce our esteemed panel. Our first witness is Dr. Phil Sadler, and Dr. Sadler is the Director of the Science Education department of the Harvard-Smithsonian

Center for Astrophysics. The Science Education Department draws on the expertise of scientists, researchers, educators, policy experts, and media professionals to develop a curricular materials for the K through 12 students and to provide continuing professional development for teachers who want to utilize these instructional materials with their students.

Our next witness to testify will be Dr. Eugene Schaffer. He is Chair of the Education Department at the University of Maryland, Baltimore County, UMBC. UMBC is unusual among universities in that it does not grant any undergraduate degrees in education, rather, college students must earn a baccalaureate degree in the field in which they will teach before enrolling in the teacher certification program. And this will certainly be one of our queries of where we go with our recommendations and with the implementation of the partnership program.

Mr. David Garner is Executive Administrator of the Urban Systemic Program, Oklahoma City Public Schools, and Mr. Garner will describe his work with Tulsa University and the University of Central Oklahoma through two NSF-funded partnership programs, the Urban Systemic Program and the Oklahoma Teacher Education Collaborative. Mr. Garner is a former middle school science teacher and two-time teacher of the year award winner.

And finally, Mr.—Dr. Carl Parravano, excuse me, is the Executive Director of the Merck Institute for Science Education, and Merck has been active in forming science education partnerships with schools, parents, policy makers, and the community members. Dr. Parravano began his outreach work while he was a professor of chemistry and chair of the Natural Science Division at the State University of New York. He saw firsthand how university professors and resources could enable K through 12 educators to improve classroom instruction and to cultivate student interest in science.

As our panelists may know your spoken testimony is limited to 5 minutes, after which the members of the Committee will have 5 minutes each to ask questions so as close as you are comfortable try to hold your initial presentation to that 5 minutes, and we will start with you, Dr. Sadler.

STATEMENT OF DR. PHILIP M. SADLER, DIRECTOR, SCIENCE EDUCATION DEPARTMENT, HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS, CAMBRIDGE, MA

Mr. SADLER. Thank you. Let us see. Is that working now? Okay. Here we go. Thanks for inviting me to testify here. It is a pleasure to be here. I am very interested in the programs that you propose, especially because I have had many of the roles myself over my career, starting as a physics major who earned my teacher's certification, then becoming a junior high math and science teacher, a business man who has hired and worked with high school graduates, an inventor who has applied my science and math knowledge to create new products which are now in use by about 12 million kids around the world every year.

I am now on the university faculty at Harvard teaching both in the astronomy department and school of education, and I direct several projects that I am going to talk about today, especially those in curriculum development and assessment and evaluation.

So at the Harvard-Smithsonian Center for Astrophysics I direct the 45-member Science Ed Department, which is part of a much larger institution, probably the largest astronomical research institution in the world with about 800 staff. And we bring together scientists and teachers to produce a great variety of materials. We produce textbooks. This is Project Star, which we developed using educational research and a lot of input from teachers and scientists, a very popular program. Other textbooks and programs for workshops and for kids from grades 4 through 12.

We invent new kinds of materials. This is a piece of high-efficiency defraction grading, which replaces for $20 something that used to cost about 1,000. So every classroom in the world can do experiments now with color and light just using an overhead projector. We also do a lot of development of tests. We have developed new kinds of standardized tests that measure a conceptual understanding of students, and on the overhead you see one of our most popular developments, unusual use of technology. We have five fully-automated telescopes on the internet, on the web, which are usable by any student in the United States in classrooms or at home. These telescopes are directed by students and take pictures which arrive back at the web site and which students can look at or other students can use. So this is an opportunity, especially for students in urban areas which don't have good views of the sky to actually study astronomy.

We also run lots of summer institutes for teachers where we bring these teachers in, they work with scientists, and help develop some of these programs. Probably our most effective program is called Project SPICA, which produced this book, and Project SPICA teachers have gone off and given workshops for nearly 20,000 teachers around the country on improved ways to teach science to kids.

We also run our own television station with Annenberg Foundation, the Annenberg/CPB Channel, in which we provide professional development for elementary teachers and upper-level teachers through lots of different kinds of programs. Probably our most well-known television program is one called The Private Universe, where we interview Harvard and MIT students as to their understanding of basic science. And the problem isn't just at the pre-college level. Only half of MIT students when given a light bulb and a battery and a piece of wire can make the light bulb light up.

So television programs and we have—so in—at our center we involve scientists along with teachers, and I think key to the quality of the programs that we have are the fact that—are three facts, key components.

One is we have institutional leadership. The head of our center, of our large center, our director, Irwin Shapiro, has made improving K through 12 science education nationally a major goal for the center. He has committed resources, space, funds, time. He has freed scientists with an interest in education to openly pursue these activities. All of our major scientific research proposals now include educational activities that involve teachers, both locally and nationally. We have outreach to museums, we are supporting the development of cutting-edge exhibits and planetarium shows. So institutional leadership is very important.

The second one is high standards. All of our educational activities are rigorously evaluated for impact. We don't have any activities where we just have a good idea and go out and try to do something. We study, we evaluate, and we publish our results in peer-reviewed journals. Our proposals compete at the NSF and other places with other institutions for Federal funding. We present papers at conferences and colloquia. Education at our center is held to the same high standards as scientific research. High standards.

The third is finding the best people. We have world-class scientists and engineers at our center, certainly at Harvard in general, and at the Smithsonian we have some pretty exceptional people. But we don't have people with all the skills necessary to pursue a science education agenda. We bring in people from the outside, we hire them to our staff, we have experts brought in in curriculum development and educational research. It is very difficult to turn a scientist into an educational researcher. It can be done. So we conduct national searches to bring in the best people from the country to add to our permanent staff. We offer sabbaticals for exemplary classroom teachers to come and join us. We have graduate students in post-doctoral fellowships so we have really exceptional people.

So I believe that the partnerships have to draw together, teachers and scientists, but they succeed only to the extent that scientists can maintain their rigorous standards for careful research and educators are respected for their skills and knowledge. It is a true partnership.

Thank you.

[The prepared statement of Philip M. Sadler follows:]

PREPARED STATEMENT OF DR. PHILIP M. SADLER

Thank you for inviting me to testify before the Subcommittee on Research of the House Committee on Science. It is a pleasure to be able to participate in this process particularly since I have lived so many of the roles that you envision being involved in *Improving Math and Science Education so No Child is Left Behind.* I have been:

- A physics major who earned my teacher certification,
- a 7th and 8th grade science and math teacher,
- a businessman who has hired and worked with high school graduates,
- an inventor who has applied my science and mathematics to create new products,
- a university faculty member in science and in education,
- a professor and mentor for 200 new science teachers,
- the director of several projects that rely on educational partnerships,
- and an educational researcher with expertise in assessment and evaluation.

The Harvard-Smithsonian Center for Astrophysics, where I direct the 45-member Science Education Department, has been described as a model for partnership activities etween teachers and scientists. The center is the largest astronomical research institution in the world with more than 800 staff. In bringing together scientists and teachers, we have produced curriculum materials that offer the excitement of scientific discovery to students in grades 4–12. We have created new kinds of standardized tests that measure conceptual understanding in astronomy and physical science. Our automated telescopes help children in urban areas take pictures of the night sky over the World-Wide Web. Thousands of teachers each month brush up on their science and learn new teaching strategies by watching our professional-development television channel, run in partnership with Annenberg/CPB. More than twenty thousand teachers have attended our workshops on how to more effectively teach science.

Key to the quality of these programs is the involvement of scientists and engineers engaged who either consult or who make a transition to full-fledged science educators. The successful educational programs at our large research institution are the result of a structured approach that overcomes barriers to involvement while maintaining high standards. The key components are:

- *Institutional leadership.* Our director has made improving K–12 science education nationally a major goal and has committed resources, space, funds, and time. This has freed scientists with an interest in education to openly pursue these activities. Major scientific research proposals now include educational activities that involve local and more distant schools. Outreach to museums is encouraged, supporting the development of cutting-edge exhibits and planetarium shows.
- *High standards.* Educational activities are rigorously evaluated for impact. Results are published in peer-reviewed journals. Proposals compete with those from other institutions for federal funding. Papers are presented at conferences and colloquia at other universities. Education is held to the same high standards as scientific research.
- *Finding the best people.* Scientists and engineers already at the our center are offered pathways for growth through visiting classrooms and involvement with ongoing projects. Where expertise is more limited, such as in curriculum development and educational research, national searches are carried out to add to the permanent staff. Sabbaticals are offered for exemplary classroom teachers and scientists from other institutions. Graduate students and postdoctoral fellows seek us out for research opportunities. Seminars draw both teachers and scientists from the local area.

I believe that partnerships can draw together teachers and scientists, but succeed only to the extent that scientists can maintain their rigorous standards for careful research and educators are respected for their skills and knowledge. Educational experiments must be evaluated and successes replicated. Concerning the proposed legislation, integration of partnership activities into existing national professional and research societies will provide a venue for comparison and evaluation. It will be productive to fund some partnership projects that are national in scope. With past initiatives as a model, conducting research studies that compare a wide variety of partnerships for impact, will help to shape the program and generate the highest possible leverage.

Answers to Questions from the Subcommittee

1. *Scientists, engineers, and mathematicians are relatively new players in the world of K–12 education and their participation is often ad-hoc and unstructured. How has the work of your Center benefited from the structured, long-term inclusion of these individuals and how can we encourage more practitioners of science, mathematics and engineering to get involved in K–12 programs?*

I am old enough to remember that scientists, engineers, and mathematicians made an enormous contribution to science and math education for the twenty years following Sputnik. I was privileged to be a student of two of the giants in science education of the time, Jerrold Zacharias of MIT and Fletcher Watson from Harvard. I feel that we owe much of our nation's current dominance in science and technology to this past partnership between federal support, scientists, and teachers. There are lessons to be learned from this history.

Our center's scientists have a tradition of responding to calls to give public talks and visit classrooms as a form of public service. Many research centers give tours and run speaker's bureaus. The reason that we have enjoyed a substantive impact on American science education is in large part a result of the commitment of many of our scientists. We provide structured opportunities to our scientists to contribute their expertise without being put in situations where their set of skills may be weak. For example, few of our scientists have experience teaching children, so we do not have them replace classroom teachers. A few examples follow:

- The Center for Astrophysics is one of the world leaders in telescope automation. Scientists and engineers helped design a network of automated telescopes for children, now stretching from Cambridge to Australia, which allow students to take pictures of astronomical objects over the World-Wide Web. Working with teachers they developed a series of investigations that helps students build their astronomical knowledge and process skills.
- A team of scientists and teachers led by the center director, Irwin Shapiro, developed the first high school astronomy textbook, basing it on solid educational research. They created unique demonstrations and experiments that

use the latest materials. Scientists tested activities and worked with high school teachers in summer institutes to bring them up-to-date on their astronomical knowledge. Scientists helped in reviewing materials and tests for accuracy while teachers tested materials in their classrooms. Meeting once a month, teachers and scientists discussed progress and problems.

- For teachers who are far from our center, we run the Anneneberg/CPB professional development television channel. Scientists have hosted programs, talked of their research, and have helped to plan the programs along with teachers. Our videos, that capture the scientific misconceptions of Harvard and MIT students, help promote the acceptance of new methods and materials for teaching science.

Our scientists often work on teams with teachers on educational projects. When scientists want to go into classrooms, we do not expect them to teach. They are paired up with a classroom teacher for the year so that they can visit on a regular basis and support the teacher who wishes to investigate some area of science. Our scientists often conduct background research to identify materials and resources, helping to increase a teacher's comfort level for teaching science. We are part of a consortium of such partnerships called Project ASTRO, started at the Astronomical Society of the Pacific.

Teachers have remarked that working with scientists has helped them better understand how the scientific enterprise is conducted. These partnerships helps teachers understand what real problems in science are. They come to see how many questions that science addresses do not yet have answers and the old answers may change in the light of new evidence.

I like to characterize how scientists and engineers have contributed in two ways. First, many have acted as consultants, providing expertise that requires little change in perspective from their scientific research. Second, and by far, the largest impact has come from individual scientists who have committed themselves to education. They have become educators. This has meant following the same approach they would use in delving into a new field of science. They have studied the problems hard, read the research literature in the field, gone to conferences to hear about the latest experiments and innovations, partnered with educational researchers and classroom teacher to plan and pursue programs. They insist on careful experimentation and evaluation of impact.

They treat education not as public service but as a scientific domain ripe for contribution.

2. *What are the barriers related to university culture, policy and reward structure that normally discourage university faculty from participating in K–12 education programs and how did the Harvard-Smithsonian Center for Astrophysics move beyond these barriers and create incentives for scientists, mathematicians and engineers to participate in your K–12 education programs?*

Universities often treat work at the K–12 level as a public service, a charitable act. Such efforts are voluntary and unstructured. They are generally not seen as part of the professional, research life of faculty. Moreover, universities are generally aloof from the practical problems of society. Tenure is generally awarded for work that your colleagues learn from, not that solves some practical problem. Among science professors and their students, teaching is seen as an art.

In my view, education schools are often out of touch with the move to national standards and standardized assessment, preferring positions that leave more freedom to teachers and minimal accountability. This highly independent, anti-testing stance may limit involvement with national programs such as the president's initiative. This attitude is in stark contrast to how science is practiced. Well-controlled educational studies, using quantitative measures appeal to scientists and engineers. The kind of careful development and evaluation of educational programs has found a more natural home at our scientific research center.

While some scientists at our center teach in Harvard's Astronomy Department, many more have no daily educational involvement. These scientists and engineers form a second cadre with an interest in education. With NASA now supporting 1–2% of their space science budgets with educational initiatives, many researchers have a path to combine their science activities with educational outreach. Housing the NASA Education Forum for Structure and Evolution of the Universe, our department helps interested scientists construct education and public outreach plans that draw upon successful programs and incorporate the findings of educational research.

At the CfA, educational activities count in performance reviews and we give an award for "Science Educator of the Year." Scientists and educators from the center have given presentations and papers at meetings throughout the U.S.

One of the most exciting and meaningful rewards for scientists engaged in education is to become a member of our department. Both a Smithsonian scientist, Dr. Matthew Schneps, and a Harvard Professor/Smithsonian Scientist Dr. Charles A. Whitney joined us as highly productive senior researchers and project leaders.

I would encourage any new partnership program to support sabbaticals for visiting scientists and teachers. These fund could also aid partnerships by funding attendance at education conferences and the acquisition of educational journals and books in research centers' libraries.

3. *How is current research on the science of learning integrated into your projects such ,that aterials you develop exploit this information to the benefit of teachers and students?*

The CfA is heavily engaged in projects that contribute to research on the science of learning. Our educators and scientists publish in educational research journals. I was privileged to receive the Journal of Research in Science Teaching Award in 1999 for work connecting new ways of measuring conceptual understanding in science through standardized tests.

Our projects begin with a thorough review of the relevant literature and we often engage other educational researchers in our activities. Our curriculum development process includes in-depth interviews of target students to ascertain their preconceptions. Activities, readings, and homework are designed to help move students from these prior beliefs to ones similar to those of scientists. Our tests and other assessment tools are use to measure conceptual change. We have found that teachers are often unaware of their students ideas prior to instruction, so our video interviews and teachers' guides make a point of identifying these alternative conceptions.

BIOGRAPHY FOR PHILIP M. SADLER, ED.D.

EDUCATION

Massachusetts Institute of Technology, Cambridge, MA	B.S. Physics, 1973
Harvard Graduate School of Education, Cambridge, MA	Ed. M, 1974, Ed. D. 1992

PROFESSIONAL EMPLOYMENT

Harvard University Graduate School of Education, Cambridge, MA Assistant Professor	9/92-present
Instructor	1991–1992
Frances W. Wright Lecturer on Celestial Navigation, Harvard University, Cambridge, MA	1990-present
Director, Science Education Department, Harvard-Smithsonian Center for Astrophysics	1992-present
Project Manager, Harvard-Smithsonian Center for Astrophysics	1985–1991
Vice President and Co-Founder, Peripheral and Software Marketing Inc., Newton, MA	1982–1985
Vice President and Co-Founder, Computer Products Marketing Inc., Newton, MA	1981–1985
Learning Technologies Inc., Somerville, MA President	1977–1985
Chairman	1977-present
Teacher (grades 7, 8) and Science Coordinator, Carroll School, Lincoln, MA	1974–1977
Staff Developer, Calculus Project, Education Development Center, Newton, MA	1973–1974
Staff Member, Mathematics Project, Educational Research Center, MIT, Cambridge, MA	1971–1973

HONORS AND AWARDS

Astronomy Education Recognition Award, Project ASTRO, Astronomical Society of the Pacific	2001
Journal of Research in Science Teaching Award	1999
Computers in Physics, Winner for MicroObservatory,American Institute of Physics (shared)	1998
Computers in Physics, Winner for Mouselab, American Institute of Physics (shared)	1994
Silver Plaque Award for "Sun, Moon, Stars," Industrial Film & Video Festival (shared)	1992
Computers in Physics, Honorable Mention for MBL Spectrometer, American Inst. of Physics (shared)	1992
Computers in Physics, Winner for Wavemaker, American Institute of Physics (shared)	1991
Margaret Noble Address, Middle Atlantic Planetarium Society	May 1991
Representative, U.S.-Soviet Commission on Education, National Academy of Education	May 1988
Executive Producer, "A Private Universe," Pyramid Films	
Blue Ribbon, American Film and Video Association (shared)	1990
Gold Medal, Documentary, Houston International Film Festival, Houston, TX (shared)	1988
Gold Plaque Award, Chicago International Film Festival (shared)	1989
Silver Apple, National Educational Film and Video Festival, Seattle, WA. (shared)	1987
Representative of the Year (Worldwide), Apple Computer (shared)	1982
U.S. Patent 4,164,829 Inflatable Structure	8/21/79
U.S. Patent 4,178,701 Cylindrical Projector	12/18/79

ADVISORY BOARDS

Design in the Science Classroom, Georgia Institute of Technology, Atlanta, GA	2000-

EDUCATION—Continued

Evolution Education Research Centre, McGill University, Montreal, Canada	1999-present
Center for Earth and Space Science Education, TERC, Cambridge, MA	1998-present
Annenberg Channel One, MCET, Cambridge, MA	1996-present
US Dept of Ed/NRC, Integrating Academic and Vocational Education, Washington, DC	1995
Astronomy and Space Science Summer Institute, University of California, Berkeley	1992–1993
Space Telescope Science Institute, Advisory Council on Education, Baltimore, MD	1994–96
Boston Museum of Science, Planetarium Advisory Committee	1992-present
Cambridge Public Schools, Science Advisory Board, Cambridge, MA	1988–1994

CONSULTING EXPERIENCE

Adler Planetarium, Chicago, IL	1997
NSTA, Scope Sequence and Coordination National Standards, Earth Science, Arlington, VA	1995–1996
AAAS Project 2061, Resources for Science Literacy. Washington, DC	1994
SEA Preservice Program Development, Sea Education Association, Woods Hole, MA	1994
Bolt, Beranek, and Newman, Cambridge, MA	1991–1992
Education Initiative in Astronomy, Space Telescope Science Institute, Washington, DC	1990
Boston Children's Museum, Boston, MA	1988–1990
Science Museum of Virginia, Richmond, Virginia	1988–1990
Lawrence Hall of Science, Berkeley, CA	1988–96
Summer Science Institute, Independent Schools Association, Concord MA	1987–1990
National Air and Space Museum Teacher Workshops, workshop leader, Washington DC	1987–1989
Amplification '86 Mathematics Institute, Harvard School of Education, Cambridge MA	1986
Apple Computer, Cupertino, CA	1981–1984
National Council of Science Museums, Calcutta, India	1981
Children's Television Workshop, New York, NY	1977–1978

TEACHER CERTIFICATION

Massachusetts Certificate #183612, General Science, Physics, Mathematics, grades 7–12	8/12/74

PEER REVIEW

National Science Foundation, Interagency Educational Research Initiative, Peer Review Panel	2000
National Science Foundation, Small Business Innovation Fund, Peer Review Panel	1999-
Journal of Science Education and Technology, Editorial Board	1999-present
International Journal of Science Education, Editorial Board	1998-present
The Physics Teacher, Reviewer	1997-present

PROFESSIONAL MEMBERSHIP

American Association for the Advancement of Science
American Astronomical Society
Astronomical Society of the Pacific
National Science Teachers Association
International Technology Educators Association
American Association of Physics Teachers
Association of Science and Technology Centers
International Planetarium Society
Institute of Navigation
American Association of Museums

PROFESSIONAL MEMBERSHIP—Continued

National Association for Research in Science Teaching

SOFTWARE, HARDWARE, WEBSITES

Deutsch, Sadler, Whitney, Enquist, and Shore, Wavemaker. Physics Academic Software, 1995

Deutsch, Sadler, Whitney. Mouselab. Sunburst Software 1996.

Antonucci and Sadler, Microcomputer-Based Spectrophotometer, Salem, MA. Deadalon Corporation, 1996.

Deutsch, Gould, Sadler, Antonucci and Leiker, MicroObservatoryNet Website, 1998.

VIDEOS

Schneps, Matthew and Sadler, Philip. A Private Universe. Annenberg/CPB, 1988.

Schneps, Griswald, and Sadler. Project STAR, Teacher-to-Teacher Series, Kendall/Hunt, 1993.

Schneps, Griswald, and Sadler. Sun, Moon, Stars/Harvard College, 1993.

Schneps, Sadler, Whitney and Shapiro, Minds Of Our Own Series, Annenberg/CPB, 1998.

BOOKS

Walton, Schey, Christie, Garfunkel & Sadler. Computer and Laboratoryalculus, Educational Development Center, Newton, MA, 1975.

Sadler, Philip et al. Apple III Certification, Apple Computer, Framingham, MA. 1982.

Sadler, Philip et al. Project STAR. Where We Are in Space and Time, Somerville, MA: Learning Technologies Inc., 1990.

Coyle, Gregory, Luzader, Sadler, and Shapiro. Project STAR. The Universe in Your Hands, Dubuque, IA: Kendall/Hunt Publishing, 1993.

Sadler, Philip. The Initial Knowledge State of High School Astronomy Students. Ed.D. Dissertation: Harvard University, 1992.

Colby, Sadler, Kratzer and Klonz. Astronomy and More: A Comprehensive Curriculum and User's Guide to the Starlab and Other Planetariums, Somerville, MA: Learning Technologies, 1998.

Coyle, Hines, Rasmussen, and Sadler. Science in Action: A Supplemental Curriculum for Middle School Physical Science, Dubuque, IA: Kendall/Hunt Publishing, 2000.

Antonucci and Sadler, Light, Color and Spectroscopy for Every Classroom. Tonawanda, NY: Science Kit and Boreal Labs, 2001.

ARTICLES, PROCEEDINGS, AND BOOK CHAPTERS

1. Sadler, Philip. Astronomy in U.S. High Schools, *COSMOS an Educational Challenge, Proceedings of GIREP,* European Space Agency, Paris, France, 1986.
2. ——. Misconceptions in Astronomy, *Proceedings of the Second International Seminar, Misconceptions and Educational Strategies in Science and Mathematics.* (ed) J. Novak, Cornell University, Vol. 3; 1987.
3. ——. Astronomy: Secret Weapon, Focal Point Editorial, *Sky & Telescope,* November 1987.
4. Lightman, Alan and ——. The Earth is Round? Who Are You Kidding? *Science and Children,* February 1988. pp. 24–26.
5. Whitney, Charles A. and ——. Intuition-Building Tool Kits for Physical Systems, *Computers in Physics Instruction,* New York: Addison-Wesley Publishing Co., 1989. pp. 462–463.
6. ——. MicroObservatory, *Proceedings of the Eleventh Annual Fairborn/Smithsonian/IAPPP Symposium,* Remote Access Automatic Telescopes, February 1990.
7. ——. William Pickering's Search for a Planet Beyond Neptune. *Journal for the History of Astronomy,* 21(1), Feb. 1990.
8. —— and Luzader, William. Science Teaching through its Astronomical Roots, *The Teaching of Astronomy,* ed. J. Pasachoff, Cambridge: Cambridge University Press, 1990, pp. 257–276.
9. ——. Project SPICA, A National Program of Astronomy Workshops, *Proceedings of the International Planetarium Society,* 1990.
10. ——. Project STAR, A High School Astronomy Curriculum, *Proceedings of the International Planetarium Society,* 1990.
11. —— and Kenneth Brecher. Astronomy as a Laboratory Science, *Proceedings of the Astronomical Society of the Pacific,* July 13, 1990.

12. ——. Projecting Spectra for Classroom Investigations. *The Physics Teacher,* 29(7), 1991, pp. 423–427.

13. ——. High School Astronomy: Characteristics and Student Learning, *Proceedings of the Workshop on Hands-on Astronomy for Education,* (ed) E.C. Pennypacker, River Edge, NJ: World Scientific, 1992.

14. Grossman, Marvin, ——, and Ward, R. Bruce. A Revolution in Elementary Science. *Harvard University Alumni Bulletin,* Fall 1992, pp. 10–12.

15. Lightman, Alan and ——. Teacher Predictions versus Actual Student Gains. *The Physics Teacher,* 31(3), 1993, pp. 162–167.

16. ——. Teachers' Misconceptions of their Students' Learning. *Proceedings of the Third International Seminar, Misconceptions and Educational Strategies in Science and Mathematics.* (ed) J. Novak, Ithaca, NY: Cornell University, 1993.

17. —— and Yossi Nussbaum. Focus on Disciplinary Issues: Earth and Space Science. *Proceedings of the Third International Seminar, Misconceptions and Educational Strategies in Science and Mathematics.* (ed) J. Novak, Ithaca, NY: Cornell University, 1993.

18. ——. An Ancient Time Machine: The Dial of Ahaz, *American Journal of Physics,* 33(3), 1995.

19. ——. Astronomy's Conceptual Hierarchy, *Astronomy Education: Current Developments, Future Coordination.* (ed) J. Percy, San Francisco: Astronomical Society of the Pacific, 6/23–25/95.

20. ——. Celestial Navigation in the Small Planetarium, *Proceedings of the European Meeting of Small and Itinerant Planetariums,* Brescia, Italy: International Planetarium Society, 10/12–16/95.

21. Leiker, P. Steven, ——, and Brecher, Kenneth. The MicroObservatory: An Automated Telescope for Education. *Robotic Telescopes, Astronomical Society of the Pacific Conference Series,* Vol. 79, 1995, pp. 93–98.

22. —— and Robert Tai. The Role of High School Physics in Preparing Students for College Physics. *The Physics Teacher* 35(5) May 1997, pp. 282–285.

23. ——. Psychometric Models of Student Conceptions in Science: Reconciling Qualitative Studies and Distractor Driven Assessment Instruments, *Journal of Research in Science Teaching,* 35(3), 1998. pp. 265–296.

24. ——. Twenty Years On The Road: The Portable Planetarium's Development and Contributions to the Teaching of Astronomy. *Proceedings of the International Planetarium Society,* London, England, June 1998.

25. —— and James Hammerman. Employing Quantitative Models of a Qualitative Admission Process: Uncovering Hidden Rules, Saving Time, and Reducing Bias, *College & University,* 74(3), 1999, pp. 8–23.

26. ——, Charles A. Whitney, Linda Shore, and Freeman Deutsch, Visualization and Representation of Physical Systems: Wavemaker as an Aid to Conceptualizing Wave Phenomena, *Journal of Science Education and Technology, 8(3), 1999, pp. 197–209.*

27. ——. The J-Curve: Documenting the "Bumpy Road" to Understanding in *Assessing Science Understanding: A Human Constructivist View* (eds.) J.J. Mintzes, J.H. Wandersee:, J.D. Novak. New York: Academic Press, 1999, pp. 249–278.

28. ——, Doug Haller, and Eliza Garfield. Observational Journals: An Aid to Sky Watching. *Journal of College Science Teaching,* 29(4) Feb. 2000, pp. 245–254.

29. ——, Roy Gould, Kenneth Brecher, and Beth Hoffman. Astronomical Experiences Using Internet-Accessible Remote Instrumentation in *Innovations in Science and Mathematics Education* (eds.) M.J. Jacobson & R.B. Kozma, Mahwah, NJ: Lawrence Erlbaum Assoc., 2000, pp. 259–286.

30. ——, Harold A. Coyle, and Marc Schwartz, Successful Engineering Competitions in the Middle School Classroom: Revealing Scientific Principles through Design Challenges, *Journal of the Learning Sciences,* 9(3), 2000, pp. 299–327.

31. ——, Roy Gould, P. Steven Leiker, Paul Antonucci, Robert Kimberk, Freeman Deutsch, and Beth Hoffman. MicroObservatory Net: A network of automated remote telescopes dedicated to educational use. *Journal of Science Education and Technology,* 10(1), 2001, pp. 39–55.

32. —— and Robert H. Tai. Success in College Physics: The Role of High School Preparation, *Science Education,* 85: 111–136, 2001.

33. Tai, Robert H. and ——. Gender Differences in Introductory Undergraduate Physics Performance: University Physics and College Physics in the United States. *International Journal of Science Education.* (in press).

SPONSORED RESEARCH GRANTS

Position	Project	Funding Institution	Duration
Co-I	From the Ground Up, Micro-Observatory Curriculum Development	NSF, Materials Development	1998–2001
PI	SEDNet: A Nationwide Educational Leadership Program	NSF, Teacher Enhancement	1998–2001
PI	DESIGNS middle school engineering curriculum	NSF, Materials Development	1995–2002
PI	ComTech—Communication Technology	NSF, ATE division	1997–2000
PI	Spectroscopy: The Universal Analytic Method	NSF, Materials Development	1996–2000
PI	Comparative Analysis of NELS 88, Decisions Pilot Study and TIMSS Data in Physics Education and Achievement	NSF, Research and Studies	1996–98
PI	A Design for an Interactive Television Series: Children's Science Television Founded on Constructivist Research	NSF, Informal Science Education, US Dept of Commerce	1995–98
PI	MicroObservatory Net	NSF, Applications of Advanced Tech	1995–98
Co-I	Misconception Video Project—documentary film on student conceptions in science	NSF, Teacher Enhancement Annenberg/CPB	1993–7
PI	MicroObservatory II—development of low-cost electronic telescope for school use	NSF Applications of Advanced Tech	1992–95
PI	A Private Universe Project Manual	Annenberg/CPB	1993
Co-I	Project ARIES, elementary school astronomy curriculum	NSF, Materials Development	1992–99
Co-I	MicroObservatory—development of low-cost electronic telescope for school use	NSF, Applications of Advanced Tech	1889–92
Co-I	InSIGHT—development of advanced simulations for introductory physics	NSF, Applications of Advanced Tech	1989–95

SPONSORED RESEARCH GRANTS—Continued

Position	Project	Funding Institution	Duration
Project Manager	Project SPICA—summer institutes to train astronomy workshop leaders (with Linda French, Ph.D., and Darrel Hoff, Ph.D.)	NSF, Teacher Enhancement	1989–94
Project Manager	Project STAR—development of high school level astronomy course	NSF, Materials Development	1985–91

CONFERENCE PRESENTATIONS OF RESEARCH

Groupe international de recherche sur L'enseignement de la physique Conference 1986—Cosmos—an Educational Challenge, Copenhagen, Denmark, August 21, 1986. Contributed paper: "Astronomy in U.S. High Schools."

NSF, Applications of Advanced Technology Project Directors' Meeting, Santa Monica, CA, December 4–5, 1987. Progress Report: "Teaching Science and Mathematics with Astronomy."

NSTA Annual Conference, Washington, DC, March 28, 1987. Contributed Paper: "Project STAR: Science Teaching through its Astronomical Roots."

Middle School Math and Science, Lesley College, Cambridge, MA, May 2, 1987. Keynote Paper: "Teaching Astronomy with Microcomputers."

American Association of Physics Teachers, Bozeman, MT, June 21, 1987. Invited Paper: "Field Tests of Project STAR Activities."

Education Development Center, Newton, MA, July 20, 1987. Colloquium: "Designing Curricula Around Research."

American Astronomical Society, Vancouver, BC, June 27, 1987. Invited Paper: "Project STAR: Science Teaching through its Astronomical Roots", Kenneth Brecher and Philip Sadler.

Misconceptions and Educational Strategies in Science and Mathematics, ——. Cornell University, July 26–29, 1987. Contributed Paper: "Misconceptions in Astronomy."

Technical Education Research Center, Cambridge, MA, September 29, 1987. Colloquium: "Exploring Student Misconceptions in Science."

NSF, Washington, DC, November 17, 1987. Invited talk: "Project STAR Results."

NSF, Project Directors' Meeting, Tempe, AZ, January 8, 1988. Contributed Paper: "Development of a Microcomputer Based Spectrophotometer." Philip M. Sadler and Charles Whitney.

NSTA, St. Louis, MO, April 8, 1988. Contributed Paper: "Project STAR: Astronomy Teaching in United States High Schools."

International Research and Exchanges Board, Moscow, USSR, May 14–16, 1988. Invited paper: "Computer Usage in Science Education."

International Planetarium Society, Biennial Conference, Richmond, VA, June 30, 1988. Invited Paper: "The Role of Activities in Teaching Astronomy."

International Astronomical Union Colloquium #105 (The Teaching of Astronomy), Williamstown, MA, July 27–30, 1988. Invited Papers: "Astronomy in U.S. High Schools" and "Astronomical Misconceptions: Identifying and Changing Them."

Astronomer for a Day, American Astronomical Society, Boston, MA. Invited paper: "Project STAR" (with Darrel Hoff). January 15, 1988.

Conference on Computers in Physics Instruction, North Carolina State University, Raleigh, NC, August 1–5, 1988. Invited Paper: "Intuition-Building Toolkits for Physical Systems," with Charles A. Whitney.

NSF Project Director's Meeting, Pittsburgh, PA, November 2–5, 1988. Invited Paper: "Physics Simulations and Telescope Automation."

Joint Center for Astrophysics and American Astronomical Society/History of Astronomy Division Symposium on the History of Astronomy, Cambridge, MA, January 7–8, 1989. Invited Paper: "William H. Pickering and the Search for a Planet Beyond Neptune."

Boston University, Boston, MA, February 15, 1989. Science Education Colloquium: "Dissemination of Project STAR."

IAPPP Symposium, Tucson, AZ, March 17, 1989. Contributed paper: "MicroObservatory."

NSF Project Directors' Meeting, Seattle, WA, April 5, 1989. Invited Paper: "Development and Testing of a New High School Astronomy Curriculum."

NSTA National Conference, Seattle, WA, April 6–9, 1989. Contributed Workshop: "Project STAR," (with Darrel Hoff).

National Education Computing Conference, Boston, MA, June 20–22, 1989. Special Session: "Teaching Astronomy with Microcomputers."

Middle School Math and Science, Lesley College, Cambridge, MA, November 4, 1989. Keynote Address: "Our Private Universes—The Role of Misconceptions in Science and Mathematics."

American Astronomical Society, Washington, DC, January 9–13, 1990. Contributed papers: "MicroObservatory" (with Kenneth Brecher) and "The Dial of Ahaz" (with Owen Gingerich).

Bolt, Beranek, and Newman, Cambridge, MA, March 22, 1990. Colloquium: "Uncovering Student Misconceptions."

Astronomical Society of the Pacific, July 13, 1990. Invited paper (with Kenneth Brecher): "Astronomy as a Laboratory Science" and "SPICA, A National Program of Astronomy Workshops."

University of Toronto, October 31, 1991. Astronomy Department Colloquium, Invited Paper: "Astronomical Misconceptions of Undergraduate Students."

NSF Project Directors' Meeting, Boston, MA, November 29–30, 1991. Invited Paper: "Investigating the Interface between Quantum and Classical Physics with Computer Tools."

NSF, Instructional Materials Development Meeting, Washington, May 15–16, 1992. Invited Paper: "Results from Project STAR."

NSF, Applications of Advanced Technology Meeting, Washington, June 29–30, 1992. Invited Papers: "The Potential for Student Research with MicroObservatory" and "Simulations and the Role of the Laboratory in Teaching Physics."

NSF Invitational Conference, Washington, DC, February, 10, 1993. Invited Paper: "Project STAR, A Curriculum that Changes Students Misconceptions."

American Association for the Advancement of Science, Boston, February 13, 1993. Poster Session: "Science Education Projects at the Harvard-Smithsonian Center for Astrophysics."

Schlumberger-Doll Research Symposium, Wallingford, CT, March 4, 1993. Invited Paper: "Children's Ideas in Science."

Astronomical Society of the Pacific, San Deigo, CA, July 14–15, 1993. Keynote: "Astronomical Misconceptions. Update on MicroObservatory."

Third International Seminar, Misconceptions and Educational Strategies in Science and Mathematics, Cornell University, August 3–4, 1993. Contributed Papers: "Teachers' Misconceptions of their Students' Learning" and " The Private Universe Project" (with Matt Schneps).

Technical Education Research Center, Cambridge, MA, September 8, 1993. Colloquium: "Mouselab: Microcomputer Based Laboratories without Transducers."

Center for the Enhancement of Science and Mathematics Education Statewide Implementation Conference, Northeastern University, Boston, MA, January 29, 1994. Invited Talk: "The Lessons of Project STAR."

NSF, Applications of Advanced Technology, Washington, DC, June 7, 1994. Invited Paper: "Remote Telescopes Over the Internet."

National Educational Computer Conference, Boston, MA, June 15, 1994. Invited Paper: "MicroObservatory, Computer Animation of Small Telescopes" (with Kenneth Brecher, Boston University).

International Planetarium Society, Cocoa Beach, FL, July 13, 1994. Invited Paper: "Astronomical Misconceptions."

American Association of Physics Teachers Conference, Orlando, FL, January 18–19, 1995. Invited Papers: "The Effects of High School Preparation on College Physics Success," "Mouselab—A Program for Learning About Kinematics" (with Freeman Deutsch, CfA), and "Student Misconceptions and the Introductory Astronomy Course."

International Planetarium Society, Conference on Portable and Itinerant Planetariums, Lumezzane, Italy, October 12–15, 1995. Invited Paper: "Teaching Navigation in the Planetarium."

International Technology Education Association Conference, Phoenix, AZ, April 1, 1996. Panel Presentation; "Technology Materials in Support of Educational Reform" (with Gerhard Salinger, NSF).

First Science Centre World Congress, Vantaa, Finland, June 15, 1996. Panel Presentation: "Mobile Planetaria" (with Lars Broman, Per Broman, and Susan Reynolds).

NSF State Systemic Initiatives, Washington, DC, June 20, 1996. Invited Exhibit: "The Private Universe Project" (with Matt Schneps).

NSF, Applications of Advanced Technologies, Component Software and Software Tools, Washington, DC, June 27, 1996. Invited Talk: "The MicroObservatory Network of Telescopes."

International Astronomical Union Education Colloquium, London, England, July 7, 1996. Invited papers: "MicroObservatory" (with Kenneth Brecher, BU), and "What to Cover and When: Using the Prerequisite Nature of the Astronomical Ideas."

American Association of Physics Teachers Conference, College Park, MD, August 7–9, 1996. Invited Papers: "Middle School Design Projects" (with Marc Schwartz, GSE Ed.D. student), "Physics Performance Factors" (with Robert Tai, GSE Ed.D. student), "Automated Telescopes on the Internet" (with Roy Gould, CfA), "Spectroscopy—The Universal Analytical Method" (with Paul Antonucci, CfA).

NSF Design Education Workshop, Technical Education Research Center, ——, Cambridge, MA, December 13, 1996. Invited Talk: "Project DESIGNS: Early Results."

American Association of Physics Teachers, Phoenix, AZ, January 4–9, 1997. Invited Paper: "Students' Astronomical Conceptions and How They Change."

Optical Society of America, New England Section, Waltham, MA, February 28, 1997. Invited Talk: "Bringing the Rainbow Down to Earth."

National Zoological Park, Smithsonian Institution, Washington, DC, March 16–18, 1997. Invited Talk: "Dialogue II: What About Diffusion? What Drives Outreach?"

4th International Seminar, Misconceptions and Educational Strategies in Science and Mathematics, Cornell University, June 14, 1997. Contributed Paper: "The Role of Misconceptions in the Evolution of Children's Ideas."

The National Academy of Education, National Meeting, Boulder, CO, September 24, 1997. "What Does It Mean to Know?"

National Association of Biology Teachers, Cambridge, MA, March 19, 1998. "Keynote: Minds of Our Own."

National Association for Research in Science Teaching, San Diego, CA, April 20–21, 1998. Contributed Paper: "Reconciling Qualitative and Quantitative Investigations of Students' Scientific Understanding Using Psychometric Measures."

American Physical Society—American Association of Physics Teachers Regional Meeting, Ball State University, May 2, 1998. Invited Talk: "Misconceptions in Physics."

International Planetarium Society, London, England, June 28, 1998. "Twenty Years On The Road: The Portable Planetarium's Development And Contributions To The Teaching Of Astronomy."

VermontFest, Nov. 5, 1998. Keynote: "The Role of Technology in Professional Development."

Lowell Regional Physics Alliance, University of Massachusetts, Lowell, December 1, 1998. Invited Talk: "The Role of High School Physics in Preparing Students for College Physics."

Astronomical Society of the Pacific, Annual Conference, Toronto, Ont., July 2, 1999. Invited Paper: "Effective Learning of Astronomy."

Harvard Graduate School of Education, Cambridge, MA, November 8, 1999. Creationism vs. Evolution Forum, Moderator.

American Association of Physics Teacher Winter Meeting, January 17–19, 2000. Contributed Papers: "Software for Teaching Spectroscopy," "Teaching Wave Mechanics with Wavemaker." Invited paper: "Prerequisite Relationships Between Astronomy Concepts."

Remote Experiments in Science Education Conference, 10/28/00, Liquid Crystal Institute, Kent State University, Kent, Ohio. Invited paper: "Student Projects Using a Worldwide Network of Remote Telescopes."

Joint American Astronomical Society—American Association of Physics Teachers, Annual Meeting, San Diego, CA, 1/7–10/01. Plenary: Preparing students for success in college physics: Which high school make the grade?. Contributed papers: "A Role for Observational Journals in Introductory Astronomy Courses," "Popper and Kuhn Come to Visit: A Nature of Science Role-play," "Students' Conceptions of Light and Color and How They Change," "From the Ground Up!: Investigations in Physical Science Using the MicroObservatory Online Telescopes." Poster: Gender and Success in Introductory College Physics.

COURSES TAUGHT

	Astronomy 2	T–210e	T–211e	T–215	T–124
Course Title	Celestial Navigation	Module on Teaching Science	Module on Teaching Science	Teaching Science	How Children Learn Science
Enrollment	FAS (and GSE)	Teacher Ed. Prg.	Teacher Ed. Prg.	Teacher Ed. Prg.	GSE
Class Hrs/ wk	5.0	1.25	1.25	2.5–>3.0	2.0
1989–90	Spring				
1990–1	Fall, Spring				
1991–2	Fall				
1992–3	Fall	Fall	Spring		
1993–4	Fall	Fall	Spring		Spring
1994–5	Fall			Fall	Spring
1995–6	Spring			Fall	
1996–97	Spring			Fall	
1997–8				Fall	Spring
1998–9	Spring			Fall	Spring
1999–2000	Spring			Fall	Spring

TEACHER WORKSHOPS AT PROFESSIONAL MEETINGS

International Planetarium Society Conference, Tucson, AZ, 7/1/86. Contributed workshop: "Activities for Teaching Astronomical Scale."

American Association of Physics Teachers, San Francisco, CA, 1/31/87. Contributed Papers: "Studying Terrestrial Spectra," "Misconceptions about Astronomy," "The State of High-School Astronomy Education."

Massachusetts Association of Science Supervisors, Framingham, MA, 5/2/87. Invited paper: "Starting an Astronomy Course in Your School."

Macademia, Boston College , Boston, MA, 5/28/87. Invited Paper: "Microcomputer-based Simulations in Astronomy."

The Independent School Association of Massachusetts, Wellesley, MA, 6/25/87. Invited Workshop: "Scale Models in Astronomy."

Astronomical Society of the Pacific, Pomona, CA, 7/15/87. Invited Paper: "Commonly Held Misconceptions in Astronomy."

National Air and Space Museum, Practical Astronomy: Time, Place, and Space Teacher Workshop, Washington, DC, 8/12/87. Invited Workshop: "Where We are in Space and Time."

NSTA Regional Conference, Pittsburgh, PA, 11/6/87. Contributed Paper: "Activities for Teaching Astronomy."

National Air and Space Museum, Practical Astronomy: Time, Place, and Space Teacher Workshop, Washington, DC, 11/21/87. Invited Workshop: Activities from "Where We are in Space and Time."

NSTA, St. Louis, MO, 4/7–12/88. Contributed Workshops: "Astronomy Share-A-Thon: A National Earth Science Teachers-Association of Astronomy Educators Workshop," "What's Up? Bringing the Universe into Your Classroom."

The Independent School Association of Massachusetts, Wellesley, MA, 6/19–24/88. Contributed Workshop: "Elementary Astronomy Activities."

Woodrow Wilson National Fellowship Foundation, Institute on High School Physics, Princeton, NJ, 7/7–8/88. Workshop: "Activities for Teaching about Light."

National Air and Space Museum, Washington, DC, 8/17–18/88. Invited Workshop: "Middle School Astronomy Activities."

Science Museum of Virginia, Science Sense Advisory Committee Meeting, Richmond, VA, 4/28/89. Invited Workshop: "Building Conceptual Understanding in Astronomy."

Independent School Association of Massachusetts, Summer Workshops for Independent School Teachers, Wellesley, MA, 6/18–23/89. Workshop for Elementary School Teachers: "Strengthening the K–8 Classroom through Science."

NSTA National Convention, Atlanta, GA, 4/5–8/90. Contributed Workshop: "Project STAR: Science Teaching through its Astronomical Roots," and "What's Up? Bringing the Universe into Your Classroom, 10th Anniversary Gala" (with Darrel Hoff).

International Planetarium Society, Borlange Conference, 7/1990. Invited Workshop: "Hands-On Methods in Portable Planetariums."

Workshop for Hands-on Astronomy for Education, Tucson: Fairborn Observatory, 11/1–4/92. Invited Paper: "High School Astronomy: Characteristics and Student Learning."

Science Teachers Association of Ontario, 11/1/91. Invited Workshop: "Activity-Based Astronomy Teaching."

NSTA, Boston, MA, March 26–28, 1992. "Astronomy Share-a-thon," "Association of Astronomy Educators Workshop."

International Planetarium Society, Salt Lake City, UT, June 25–27, 1992. Workshop: "Teaching Celestial Navigation in the Planetarium," and "Activities from Project STAR."

Lawrence Hall of Science, Participatory Oriented Planetarium Institute, University of California, Berkeley, July 16, 1992. Workshop: "Astronomical Misconceptions and Scale Model Activities."

NSTA, St. Louis, MO, April 1, 1993. Workshop: "Project SPICA Activities."

Lawrence Hall of Science, Astronomy and Space Science Summer Institute, University of California, Berkeley, July 20, 1993. Workshop: "Children's Astronomical Ideas and their Origins."

NSF, Applications of Advanced Technology Meeting, Washington, DC, June 29–30, 1993. Invited Paper: "The Progress of MicroObservatory and InSIGHT Simulations."

Astronomical Society of the Pacific, San Diego, CA, July 14–15, 1993. Invited Workshop: "Astronomy Education."

Lawrence Hall of Science, Participatory Oriented Planetarium Institute, July 20, 1993. Workshop: "Astronomical Misconceptions and Planetarium Activities."

NSTA Conference, Phil., PA, March 23–25, 1995. Workshop: "Using the MicroObservatory" (with Steve Leiker).

Astronomical Soc. of the Pacific, College Park, MD, 6/24/95. Invited Paper: "Astronomy's Conceptual Hierarchy."

NSTA Conference, Ocho Rios, Jamaica, July 28–30, 1995. Invited Workshop: "Size and Scale in the Universe: Children's Ideas and How They Change."

NSTA Conference, St. Louis, MO, March 28, 1996. Short Course: "The Private Universe Project" (with Nancy Finkelstein, CfA).

Middle Atlantic Planetarium Conference, Boston, MA, May 9, 1996. Workshop: "Celestial Navigation in the Small Planetarium."

NSTA Conference, New Orleans, LA, April 5–7, 1997. Workshop: "DESIGNS Challenges."

NSTA Conference, Anaheim, CA, April 16, 1998. Workshop: "Teaching Physical Science with Design Challenges."

Project ASTRO, Boston Museum of Science, June 25, 1999. Workshop: "Children's Astronomical Misconceptions."

Malden High School, Malden, MA, October 29, 1999. Inservice Workshop: "Children's Mental Models."

NSTA Conference, Orlando, FL, April 8, 2000. Workshop: "Putting a Charge in Physical Science."

Project ASTRO, Boston Museum of Science, July 8, 2000. Workshop: "Using Spectroscopy to Teach Astronomy."

Lesley College Teaching Interns, 10/12/00. "Teaching Science through Design Challenges." Brookline Public Schools.

Harvard-Smithsonian Center for Astrophysics

60 Garden Street, Cambridge, MA 02138

April 30, 2001

The Honorable Nick Smith, Chairman
Subcommittee on Research
U.S. House of Representatives Committee on Science
Suite 2320 Rayburn House Office Building
Washington, DC 20515-6301

Dear Mr. Chairman:

Thank you for the invitation to testify before the Subcommittee on Research of U.S. House of Representatives Committee on Science On May 2, 2001. As required by the rules governing witness testimony, I am disclosing the source of my Federal Government funding that supports my work in the area of science education.

The Science Education Department at the Harvard-Smithsonian Center for Astrophysics is supported by grants from the National Aeronautics and Space Administration, the National Science Foundation, and the Smithsonian Institution.

Sincerely yours,

Philip M. Sadler, Ed.D., Director
Science Education Department

HARVARD COLLEGE OBSERVATORY
Established 1839

SMITHSONIAN ASTROPHYSICAL OBSERVATORY
Established 1890

The Role of Research Institutions in Improving K-12 Science Teaching

Philip M. Sadler, Ed.D.
Director, Science Education Department
Harvard-Smithsonian
Center for Astrophysics

Harvard-Smithsonian Center for Astrophysics

- Largest astronomical research institution in the world
- A partnership between:
  - Harvard's Department of Astronomy
  - Harvard College Observatory
  - Smithsonian Astrophysical Observatory
- More than 200 scientists in a staff of over 800
- Telescopes on earth and in space
- A leader in
  - The structure and evolution of the universe
  - Search for extra-solar planets
  - Sun's impact on the earth
  - X-ray astronomy with Chandra
  - Instrument design
- Science Education K-12
  - Professional Development of Teachers and Scientists
  - Informal Science
  - Curriculum development
  - Educational Technologies
  - Community programs
  - Educational research

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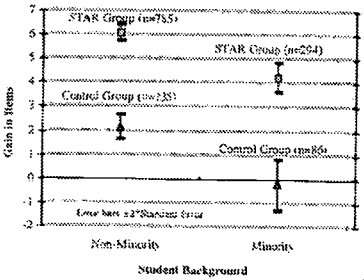
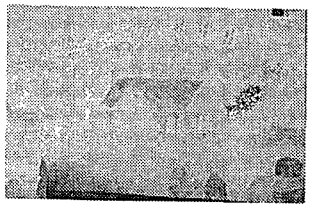


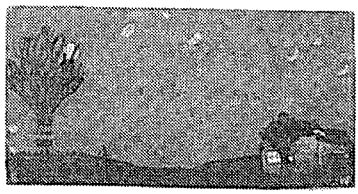
Project STAR proved to be effective for students of a variety of backgrounds

Project STAR students testify before Sen. John Kerry at a congressional hearing on science education

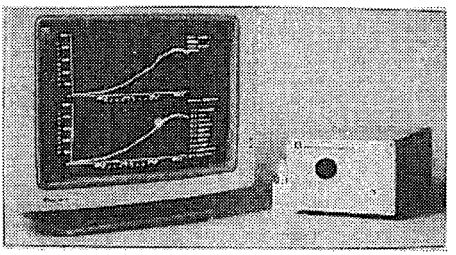
Students plot the shadow of the sun to find its path through the sky (courtesy Gary Sampson)



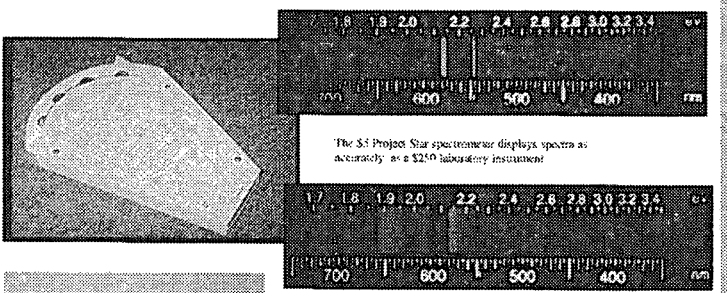
Students journals of the position of the sun (above) and the moon (below) are popular methods to recording changes in the heavens



A team of sun scientists volunteered to test each activity. Here are shown Matt Selinger and Charles Whitney (CfA) and Kenneth Brecher (Boston University)

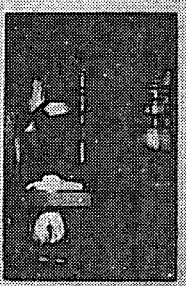


Filter characteristics are easy to measure with the Microcomputer Based Spectrophotometer (photo courtesy of Davidson Corporation).

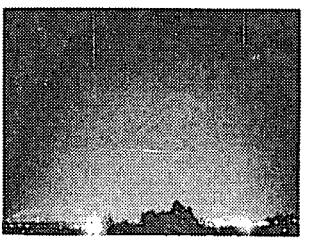


The $5 Project Star spectrometer displays spectra as accurately as a $250 laboratory instrument.

The Physics Teacher

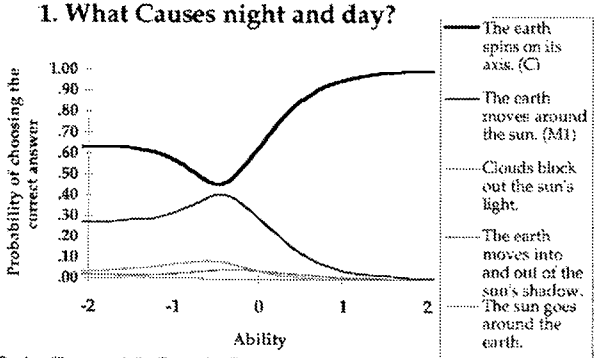


By developing high-efficiency, linear holographic diffraction gratings, we have made possible many experiments and demonstrations including spectrum projection using (my head) and overhead projector (left), and spectral photography using an ordinary camera (right).



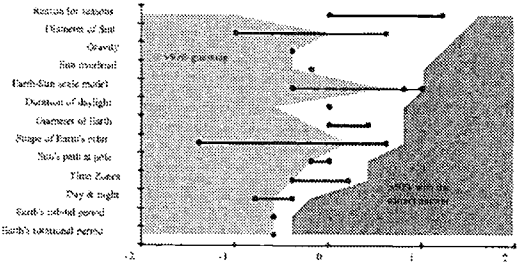
streetlights reveal their composition through a diffraction grating in the same way that stars do through telescopic spectrometers.

1. What Causes night and day?

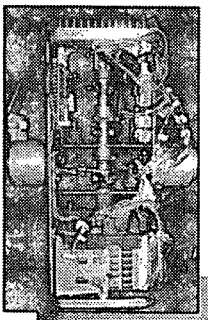


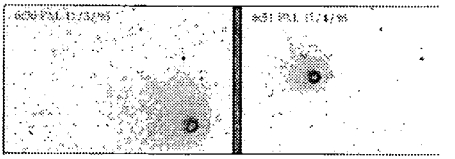
Item Option Characteristic Curve for The Cause of Day and Night. The probability of selecting the correct answer (C), that the earth spins, is lower in students of moderate abilities than those of low abilities or high abilities. This corresponds to an increase in preference for the incorrect notion of the earth's orbit being responsible (M1).

Representation of the Cognitive Range of Astronomical Concepts



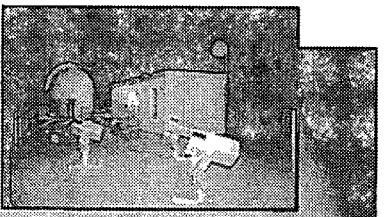
Cognitive range for items dealing with the earth and sun. Red circles mark the peak for a particular alternative conception, connect together with blue lines. White region marks where >50% of students are neither guessing or correct.



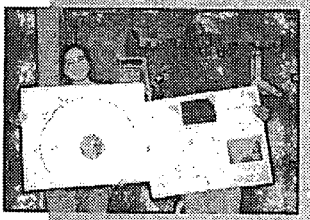


Images of Comet Hale-Bopp (in negative). These were taken one day apart by 12th grade students from the Brooke School, North Andover, MA. Note that the comet is moving against the background of stars in the direction of its tail.

Each instrument is self-contained and environmentally sealed, enclosing a computer that both points and monitors viewing conditions.



These MicroObservatories being tested.



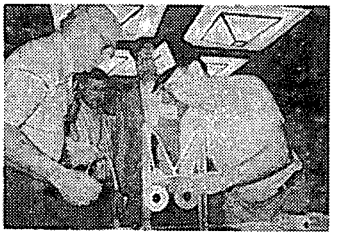
High school students show off their projects (above), while second graders study the moon (below).

Sunspots are very popular subjects.

Student Images of the moon. Raw data is on the left. Image processed for increased clarity and contrast on the right.

Professional Development of Teachers

- Built a program of 9 types of summer institutes for teachers of science
  - Leadership institutes — aids teachers in running workshops at conferences
    - SPICA — hands-on astronomy activities for grades K-9
    - SEDNet — dissemination through Christa McAuliffe Centers
  - development workshops — aid in the creation of new teaching materials
  - By video and web courses - Annenberg Channel
  - Summer institutes for teachers
  - Workshops at professional meetings
  - Sabbatical and fellowship programs
  - Training of new teachers



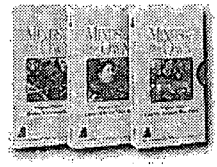
Technology teachers compete to build a tunnel using the least material

A Private Universe documents students' ideas through their own drawings and explanations

Smithsonian Institution

The Annenberg/CPB Projects

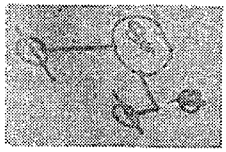
Creating a video is the work of many specialists, directors, sound engineers, cameraperson and interviewer

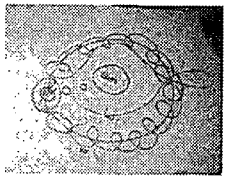


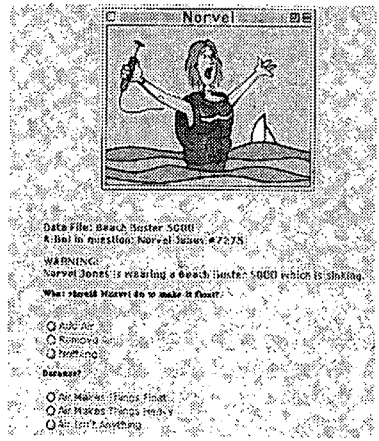
Minds of Our Own consists of 3 one hour programs broadcast on PBS in 1997-98. It explores the ideas of students as they come to understand scientific concepts

A Private Universe documents students' ideas through their own drawings and explanations

Technical Difficulties explores the variety of conceptions that learners hold through video and website







Chairman SMITH. Dr. Sadler, Thank you. Dr. Schaffer.

STATEMENT OF DR. EUGENE C. SCHAFFER, CHAIR AND PROFESSOR, DEPARTMENT OF EDUCATION, UNIVERSITY OF MARYLAND BALTIMORE COUNTY, BALTIMORE, MARYLAND

Mr. SCHAFFER. I would like to speak to four particular areas. My interest and background is in the preparation of teachers both at the undergraduate and graduate level, and over the years, and there have been quite a few of them, I have found some things that seem to be very important that have been incorporated into a number of programs.

I recently moved to Baltimore and to the University of Maryland Baltimore County. One of the things that made this particular University of Maryland campus interesting was its strength in science and mathematics and its interest and commitment in teaching.

The first thing that is true that was mentioned earlier was that our programs are all based in the arts and science field to begin with. This means everyone whether the teach kindergarten or they teach 12th grade has a major in the arts and sciences. This by itself is not enough. We also give a very strong pedagogy program that is based predominantly in the field and is organized around a number of specific elements such as subject matter methodology, literacy, diversity, and special needs. As students go through these undergraduate programs they are also in a continuous field placement, and this ends in a 100-day internship program that spans from the beginning of the year to the end so that they can see how to organize a classroom, run a classroom, and come to conclusion at the other end with a strong effort to improve student's learning.

So it is, again, focused very much on the K–12 program. I think there are two particular things about this that is critical in our programs.

First of all, we are well aware that 66 percent of our students come to us at the undergraduate level from community colleges. At this end we have developed what is called a 2+2+2 program. We meet with juniors and seniors in high school and help them plan their education. They also can take course work in the community colleges while they are in high school that assist them both in the area of teaching, if that is their interest, or in sciences. As they move through they are jointly advised and they are jointly admitted both to the under—to the community college and also to the University of Maryland Baltimore County. And they can complete that program with full knowledge that their course work will transfer from one program to another.

So this we think, first of all, promotes recruiting and also retention of these people waiting until—rather than waiting until they get to be juniors in college to start taking education course work or their majors. So this is a different kind of program.

A second program we have in place is really our post-baccalaureate program that leads to a Master's of arts in teaching. And I think that is the first element. For those people coming back for licensure or certification they are first of all going to receive an advanced degree. We try to make this coursework as flexible as possible, evenings, weekends, modulized scheduling, integration of both content and also of the methodology at the same time. And

we offer financial packages. I will come back to the financial packages in a minute.

So that is a little bit of the background. I want to go back just for a moment to the 100-day internship. These are jointly planned between the school districts and the university. We often start with what the university has—or excuse me, what the school district has in mind. I will give a very brief example. We have a school district that identified reading and writing as being critical. We have designed both grant work and programs that support their particular needs, and our students work with them all during this 100 days, as well as teaching, to increase the performance of their own children, the students in that program, in the areas of reading and writing.

A particular program I want to mention that is a nationally—National Science Foundation grant, which was the Maryland Collaborative Teacher Preparation Grant. This worked very much for the improvement of middle grades education, 8 year olds through 14. We used specially designed courses, internships, and also in the first year of teaching we supported them through a strong mentoring program.

I just want to come back to the science courses that they were taking. What they asked the teachers were—this was a biology teacher who was teaching a basic biology program. He said, well, what do you teach? And he asked the different grade level teachers, and what you got was this enormous array of topics that they have to cover between third grade and eighth grade. And he said, "Oh. I think I have to go back and redesign my course." This fellow's name is Phil Sokolove, and to this day he is back in the programs looking for ways to improve his basic science courses, not just for teachers but for science majors as well to be more hands-on, be more integrated, and more articulated across times. It has been a real strong program. That is just one outcome of that particular program.

I am going to mention another program that I think is very important. This program is called the Urban Teacher Education Program. It actually is K–12, and it is out of the Department of Education run by Johns Hopkins, UMBC, and Morgan State all in Maryland. What we are doing is for post-baccalaureate folks, putting them in urban settings with intense support and at the same time teaching the coursework in the combination of methodology and content. And the intent of this one is to be very supportive, and in some cases these folks are really not ready to teach science, and so what we have to do is work with them on their science skills as well as on their educational skills. This is about a 3-year program.

And now I am going to come to what I will call the financial package. How do you get people to move from their current jobs to this particular circumstance? And quickly, I think what we have tried to do is not only put together tuition scholarships and support but computers, books, and I would—and we are now looking at childcare for some of these folks so that they complete both programs at the same time. I realize I am out of time. Let me just say very quickly, and I haven't really gotten to collaboration, although I think it is quite obvious. One more, just one more small element.

We are working currently with engineering deans and education deans to support an integrated program that brings problem solving K–12. And I could go on with a number of other programs. What works? Strong content and inquiry skills among our teachers. Strong support and mentoring of those not just by teachers but by principals as well. A strong collaborative model. We are now including places like the Chesapeake Bay Foundation in a lot of our coursework. And continuing to get a lot of support from the university and from both arts and sciences and education. Thank you very much.

[The prepared statement of Dr. Eugene Schaffer follows:]

PREPARED STATEMENT OF EUGENE CARL SCHAFFER

Thank you for inviting me to testify regarding developing high quality science and mathematics education programs for all students. I would like to focus my comments on the content of science education, innovation in programs, delivery of programs and increased collaboration. Most of my comments are informed by findings based on practical problem-solving strategies and thoughtful, research-based efforts developed by faculty at University of Maryland Baltimore County's (UMBC) and used to create successful teacher preparation programs.

The first of UMBC's efforts has been the conscious effort by the faculty of the Education Department to assure the program's graduates are well prepared for the classroom. UMBC requires all teacher education graduates to obtain a degree with a major in the subject area to be taught, plus course work and on-going field experiences. There are no undergraduate education majors at UMBC. Their coursework includes learning theory, human development, subject-matter teaching methods, use of technology, classroom organization and management, reading, diversity and the education of students with special needs. UMBC's Teacher candidates participate in a 100-day internship in a partnership school prior to their graduation or certification.

These standards for content and pedagogy are the same for community college transfer students and post-baccalaureate students returning for a certificate to teach. The performance of our community college transfers is of keen interest to the department as over 65% of our undergraduates come from this population. Our interest in our post-baccalaureate students is equally strong as this group of teacher candidates supplies most of our science and mathematics teacher candidates.

Standards and recruitment alone will not give the nation enough high quality teachers in science and mathematics. To support the community college students, the university has reached out to our high schools and community colleges through arrangements called 2+2+2 agreements, which permit students to move rapidly and easily between the institutions. The agreements include advising and support for high school students, joint admission to the community colleges and UMBC, acceptance of all transfer courses, and scholarships for students in the program. For our post-baccalaureate students who are changing careers, we offer graduate degrees connected to the course work as recognition of their work, flexible course schedules, and in some programs financial packages the permit easy transitions between their current employment and teaching. I will speak in more detail about the "packages" later in my testimony. We believe these strong content-orient teacher education requirements provide a long-term strength to our students and prepare them for the demanding and changing profession they have chosen.

Throughout the program, we support teacher candidates to become successful teachers by participating in 100-day internships at partnership schools during their last year of the program. Partnership schools are collaboratively formed between schools systems and the university to employ the resources of Pre-K–12 and higher education to improve teacher preparation, continued professional development, action research and student achievement. Called Professional Development School Cluster Partnerships (PDS), the PDS seeks to create a community of learners at all levels, bridge theory and practice and create a school culture where inquiry, action research and reflection are ongoing and valued professional practices. The emphasis on content knowledge and extended field experiences or internships comes from numerous studies, professional organizations standards, and feedback from teachers, principals and supervisors. These programs can be enhanced and strengthen through a number of strategies, but are not enough however to assure sufficient numbers of enough high quality teachers for the profession.

I would like to briefly describe four programs at UMBC that provide opportunities for students to become teachers or for teachers to enhance their specific subject matter knowledge particularly in the sciences. The first program, The Elementary Science Integration Project (ESIP) *www.umbc/edu/ESIP*, is a National Science Foundation (NSF)-supported, University of Maryland Baltimore County-sponsored consortium of elementary and middle school teachers who are engaged in enhancing and integrating science learning in kindergarten through eighth grade. Through summer institutes, university staff support, a variety of professional resources and contacts, meetings, workshops, and teacher-to-teacher dialogue and networking, ESIP participants investigate connections between science and other curricular areas, particularly reading and writing. Participants, many of whom admit that they enter the program uncomfortable with science, come to the project with a diversity of experiences, challenges, and strengths, and all are interested in exploring new ways to encourage scientific inquiry in their classrooms.

ESIP is designed as a teacher-to-teacher forum through which participants engage in authentic science investigation, collaborate with exceptional teachers, practice models of scientific inquiry and meaningful curricular integration, and meet professional scientists and authors of children's science books. Summer institutes, academic year follow-up, and staff support, as well as liaisons with school districts, professional organizations, and content experts are integral pieces of the program. Action research, publication, and a commitment to dissemination are key responsibilities of teacher participants.

Teachers who participate in ESIP programs take part in their own scientific inquiry and engage in productive questioning skills, investigation strategies, data collection techniques, and communication strategies that include reading, writing, listening, and speaking. They identify links between local science curricula and standards and other disciplines, especially reading and writing as they explore strategies that allow students to identify their own scientific questions and build on their own backgrounds, strengths, and learning styles. Teachers are provided time to reflect on their own classroom practice and conduct action research projects.

The Elementary Science Integration Project (ESIP) grew out of the work of Dr. Wendy Saul, Professor of Education at UMBC, who built on her expertise in language arts and literature in elementary classrooms and her increasing awareness of and attention to the incorporation of authentic science investigation in classroom practice. Dr. Saul developed a program through which elementary and middle school teachers could use inquiry science as the basis for meaningful curricular integration (most specifically, purposeful reading and writing). Based on these efforts, the teachers in the project turned out significant contributions to the field of science education that include five books, six articles and two videos related to the teaching of science. Since the inception of the program, six ESIP teachers received the Presidential Award for Excellence in Science Teaching.

One current effort of the ESIP project includes a teacher-led conference called: Science Stories, Classroom Stories: A Tribute to Jean Craighead George to be held May 5, 2001 at UMBC. The keynote speaker will be the award-winning author Jean Craighead George, frequent collaborator with the ESIP project. You are all invited.

A second effort of this NSF supported project, The Kids' Inquiry Conference (KIC) grew out of ESIP teachers' interest in finding an alternative to the traditional science fairs. In place of the competition that is emphasized in the science fair, KIC is modeled after professional science conferences. The main goals of the student conference are to provide children with opportunities to share the excitement of their discoveries with students from different schools, to critically consider the credibility of their own research, and to draw upon the discoveries of other student-scientists. We hope that this concept—children sharing authentic science in a non-competitive and supportive atmosphere—will be stretched and modified to suit the needs of many student-scientists and their teachers. You can find out a great deal more about this program at *www.umbc/edu/kic*. I recommend this site. In particular, there is a report from Megan Dieckman who discusses her initial foray into original scientific investigations of polymer as part of the only girl-boy group in the fourth grade. It is a glimpse into a young person coming to scientific inquiry in a manner we would wish for all children. From this beginning in the Fourth grade to her current junior year in high school, Megan continues her work linking science and literary. She has been accepted into the prestigious University of Virginia's Summer Writing Program based on a work submitted for review at UVa of her experiences in ESIP's Kids' Inquiry Conference.

There is a great deal to learn from ESIP and projects like it. For example, there is acceptance and interest of elementary teachers to work in an area they often shy away from or consider "less essential" or critical than reading or mathematics when they learn to integrate science into the school day. Science and literacy are better

understood as mutually beneficial when intertwined in teaching. Original readings in science, children books on science and resources including tapes, websites, and projects with working scientists are powerful tools for the classroom. Teachers also find science meaningful when they and their students act as scientists rather than consumers of science. It takes time and reflection for elementary teachers to become comfortable with science content and teaching it in the classroom. Each of these ESIP ideas and many more can form the foundation for future projects, materials and teacher training in science.

If this project is good news for science education in the elementary grades, there are equally promising programs for the middle grades. The Maryland Collaborative for Teacher Preparation (MCTP) is a statewide undergraduate program for students who plan to become upper elementary or middle school teachers. The Collaborative's goal is to produce teachers who are confident teaching mathematics and science, and who can provide an exciting and challenging learning environment for all students.

This undergraduate program includes specially designed courses in science and mathematics, taught by instructors committed to a hands-on interdisciplinary approach. Internship experiences offer genuine research opportunities in business, industrial and scientific settings and teaching experiences in science centers, zoos and other institutions. The MTCP program also provides modern technology, placement assistance, support for the first year of teaching and financial support. Teachers graduating from this gain a deeper understanding of science and mathematics and strategies for interactive teaching of their subject through a deeper conceptual understanding of science and mathematics. At UMBC, this project also led to the significant involvement of members of the Biology Department in the teaching of basic freshman coursework from an integrative and hands-on approach. Their instruction was observed by members of the education faculty for teaching effectiveness and subject matter linkage to K–12 school curriculum. To this day, members of the science faculty participate in the discussion of the quality of undergraduate teaching. Also, research on teaching is ongoing and expanding understanding of interactive teaching impact on student learning and student commitment to the sciences.

The contribution of this NSF grant to teaching at both the middle grades level and the undergraduate level suggests long-term study of science teaching that can improve the teaching of science at all levels. The extension of this work to teacher in-service and graduate-level programs is clearly an area needing more attention and review. Attention in science instruction for teachers is not just an issue of the quality of teaching. It is increasingly clear that it is difficult for teachers and prospective teachers to gain the necessary science and mathematics content coursework to gain a deep understanding of science and mathematics.

Two problems face students returning for science or mathematics course work. One is the lack of available courses in evenings, weekends or summers when they are available to attend classes. The demands of the university for research and publications often causes the faculty in the sciences and mathematics to work on research projects in industry, and government, or on grants during the summer. Few courses are taught in the evening or weekends as well as most faculty members teach during the day to full time graduate students. Classroom teachers needing advanced course work to meet content requirements often are sent to community colleges to complete the necessary hours for a program. While community colleges offer significant value to students, the community college mission does not include advanced level undergraduate or graduate coursework for return students.

When teachers and teacher candidates can register for university courses taught at the graduate level, the course often focus on a very narrow area of study, or is outside of the undergraduate expertise of the teacher, or is in an area unrelated to high school curriculum. These offerings are often of little value to the teacher in his or her work in middle or high schools and yet, demand significant effort to gain understanding and success particularly when, for example, Chemistry major may be forced to take advanced Biology course work or a biologist to take physics. This lack of fit often discourages teachers or teacher candidates from updating or enhancing their content knowledge. There are strategies to overcome these problems.

The University of North Carolina System provides math and science instruction at six centers located at universities throughout the state. The centers promote collaboration on workshops, course work and research among public schools, departments of education and departments of mathematics and the sciences. These centers offer course work in the sciences and mathematics at times teachers can attend and develop rigorous courses related to teachers' academic areas of instruction. This is a step in the right direction, but in many locations it remains difficult for teacher candidates to gain the necessary background to complete science and mathematics programs. This impediment often reduces the number of interested postgraduate

teacher candidates who, if they remain committed to teaching, find a certification area other than mathematics or science to fulfill their dreams.

The Urban Teacher Education Program (UTE) is a UMBC post baccalaureate teacher program *www.umbc.edu.ute* worth examination for its contribution of a strategy to recruit teachers and to integrate content and pedagogy in their education. It is not a science education program, but it holds promise for recruitment and retention of science teachers in our most diverse and disadvantaged urban settings. Briefly, the UTE program is part of a collaborative program with The Johns Hopkins University, and Morgan State University to recruit and retain high quality teachers for urban settings. The two elements of particular interest to this committee are (1) The integrated instructional strategy used to teach content and pedagogy and (2) The recruitment strategies used to interest prospective teachers in urban teaching. Building on the K–12 curriculum, professional society standards and national standards for teaching, the UTE program offers modules of instruction for students to meet a competency-based certification program. The teachers learn the content while learning strategies to teach their students the same materials. Most of these teacher candidates are working in urban settings in Baltimore and neighboring school districts as provisional teachers. The teachers use the integrated materials in the classroom soon after they learned it in the classes. Teachers complete this program while working full time in the schools and devoting weekends, summers and evenings to their courses. These teachers also receive intensive mentoring and supervisory support while learning to work in urban settings.

The recruitment element of the program provides tuition, salary or stipend, books and computers to teachers committed to a teaching career in urban schools. By offering a "package" of financial incentives and support to teachers that covers their transition to a new location and position, the school districts and university can attract teachers for urban positions. The support for this package is a combination of funding from the school systems, university, and federal grants. A creative model for scholarships and teaching support could be developed from this current model for science and mathematics teachers that might be similar to packages given employees of firms with special skills who have been asked to change locations or given promotions. Recruiting programs that offer support other than salary differentiation may be a more successful and less divisive method to recruit teachers to areas of shortage than differentiated pay.

The list of offerings and programs at UMBC could go on, but I will only mention two more. The first is Department of Biological Sciences summer workshops for high school teachers. This one-week hands-on workshop on recombinant DNA technology, and was offered by Julie Wolf, an instructor from the Applied Molecular Biology Program, in collaboration with a high school teacher from Mt. St. Joseph High School. The second is an ecology program for teachers through the Chesapeake Bay Foundation in collaboration with UMBC's Department of Education. This site-based program involves teachers in exploring the importance of the Bay to the Baltimore region and all ecological elements of the community from Hagerstown in the west to Chestertown on the Eastern Shore.

This inquiry-driven program communicates scientific inquiry through materials, workshops and mentoring. As a field-based program the course work offers hands-on activities for K–12 teachers that they can take back to classes as both content and method. UMBC offers these courses for credit and has submitted a proposal for a series of courses that will lead to a graduate certificate in ecological studies for teachers in recognition of their expertise. This certificate may become a content strand of graduate degrees in the future.

The theme of these last two programs is collaboration. We have not yet tapped all of the resources available to us. Collaboration is difficult and time-consuming work, but support for inventive collaborations can make the sum greater than the parts for teachers and children. The two collaborations here are department to department and between institutions. There are equally beneficial program collaborations among schools, universities and businesses that can be explored for the improvement of teaching and learning.

Current Plans and Activities

If I may, I will use a personal story to illustrate our direction at UMBC. My 13 year-old son, Stefan, is beginning to explore career ideas. He asked the other day "What does an engineer's do?" Later the same day, he was studying parabolas in mathematics and asked, "What will I ever use this for?" Ever the teacher, I took him out to look for curved shapes in the built world. I showed him circular stairs built by his great uncle who had a 6th grade education, but who could design and build the most complex stairs. With my background in English and History, I was

no more prepared to assist him with his questions than I was to build the stairs. What do engineers do?

Shlomo Carmi, Dean of Engineering and passionate promoter of Engineering and Education, says Engineering is the invisible profession. From my own experiences, my son's and my work with schools supports this idea. But this can change. Since my arrival at UMBC last fall, I have had the privilege work with the College of Engineering to improve teaching in Engineering classes, increase awareness of engineering among K–12 students and teachers, and develop ideas to increase our ability to teach mathematics and science through engineering. The most immediate and tangible outcomes of these activities is working with the Institute of Electrical and Electronics Engineers, Inc *www.ieee.org* to bring together 50 deans of education and their 50 counterparts in engineering to discuss K–16 curriculum from their own perspectives. *Taking the Lead: A Deans Summit on Education for a Technological World* is scheduled for the October 1–2 2001 in Baltimore. This conference has the goal of making engineering more visible in K–12 education and improving the teaching in engineering schools. In particular, the Deans will discuss potential integration of mathematics, science, technology and engineering in K–12 schools such as those implemented by the State of Massachusetts, the preparation for both pre-service and in-service teachers, and the development of hands-on training for teachers of science and mathematics using engineering problems. The goals of the conference are also to work with engineering faculty to help enhance moving engineers into teacher training programs. As an outcome of the meeting, it is hoped all of the participating schools will develop a specific, realistic action plan to begin collaborations on campus and form better collaborations with community colleges. AT UMBC, we are circulating a proposal to create an engineering and education center for the promotion of engineering education and we are reaching out to schools in the community to create a problem-solving course at the high school level.

The university is also in discussion with the schools and business community to develop a K–12 program that provides internships & jobs w/leading businesses, certificate programs, (e.g., Cisco, A+, etc.,) Instructional Technology (IT) internships linked to coursework and post-secondary scholarships for IT Academy students. The Academy would offer curricula tailored to regional IT industry and post-secondary academic standards, infuse technology-internship hands-on activities into the classroom and offer academic support for pre-identified students and their parents. The school would use a small schools approach to HS reform with curricular, financial, staffing, and scheduling autonomy and it would begin small, enroll new cohort of students each year. UMBC would recruit and prepare teachers. The program would offer incentives for recruiting and retaining faculty, internship-enhanced technical training for faculty and a problem- and performance-based program. Student support and parent engagement would be critical to the success of the program as well as high school to university academic and social supports.

UMBC initiated advisory boards among the arts and science programs to foster relationships among schools, community colleges and the university that permit candid conversations about some challenging issues. Student preparedness, content-preparation of teachers, articulation with community colleges, the nature and quality of the transfer experience, advisement practices, assessment and accountability in the high schools, teacher professional development, expectation differences across the 12–13 boundary, and post-secondary teacher preparation curriculum have all received attention from the groups at some time or the other. Outgrowth from these conversations are numerous and have included: environmental scans of student preparation in the high schools, summer credit-bearing graduate courses in disciplines for high school teachers, articulation discussions and agreements with community colleges, hosting of special activities for high school students, and establishment of focus groups or special task forces to look at specific issues with supervisory level personnel and faculty from UMBC.

This review of UMBC's efforts and dreams to improve the teaching of mathematics and science is incomplete, but I hope you have profited from this summary and the contributions these findings may make to future support of science and learning teaching and learning. As I noted in my opening statement, I focused my comments on the content of science and mathematics education, innovation in programs, delivery of programs and increased collaboration. The pressures to place teachers in front of classrooms are enormous and school system cannot disregard their mandates to teach all their children. Yet, we can not permit teachers who have not met rigorous standards to teach in our classrooms. We must find the will to insist on the standards and provide the resources to assist our citizens to become teachers. To this end, I encourage you to consider the following suggestions as you deliberate future support of science and mathematics education.

I would like to see high school teachers, and even middle school teachers, be confident that they are experts in the topics they teach and feel up-to-date their field. To this end the support of additional course work and workshop opportunities are needed for teachers continuing in the profession as well as those new to the held. The course work must be rigorous and, at the same time, related to the content of high schools and middle schools. Yet these offerings must permit teachers, and teacher candidates to use a variety of instructional models to meet their own time constraints. These alternatives may include modules, on-line or web-based instruction as well as weekend and short-term courses. The Chautaugua-style program used by NSF with college faculty have a great deal to offer classroom teachers who are asked to spend more time in school during the year and, in many states, have a longer school year then just a few years ago. Also, I have used the idea of "hand-on instruction." What I have in mind is suggested in the work of the Chesapeake Bay Foundations inquiry models or Wendy Saul's ESIP where teachers have more freedom to try their own way of instilling enthusiasm for their topic in the student. The Kids Inquiry Conference is just such an outgrowth of teacher-developed strategies.

Recruitment and retention are continuing themes in teacher education. I do recommend a more complete scholarship package that uses the strategies business use to attract and maintain faculty. Training, development, and transition funding to begin a new career could be part of these packages. You may wish to consider moving or technology support as part of this funding. But let me offer a caveat as well. As can be seen from the UTE program, mentoring is a critical part of teacher success. I recommend that scholarship support be given only with a strong mentoring program to assure teachers remain and succeed in their positions. While mentoring programs may seem expensive at first, the cost of continually finding, training and retaining new teachers is both financially draining and detrimental to the establishment of stable and knowledgeable school faculties.

Two elements of mentoring are often overlooked and I want be particularly explicit about these two areas. In the first year of teaching, support is often situational and supportive. "How do I handle this situation?" or "Am I a good teacher are critical issues?" Often by the second year more question emerge such as "What is the best way to teach photosynthesis?" or "How do you get your students to understand the concept of mass?" In these later cases, mentoring by content specialists is critical. While mentoring to retain teachers has gained support, little research on determining the importance of content effectives in the second or third year has been undertaken. A focus on content mentoring is well worth consideration. The assurance of a qualified content mentor for new teachers, particularly in their second and third year, will increase their likelihood of staying in teaching and becoming an effective teacher.

The second emphasis of mentoring must be on the role of the school leadership. Like any other leader, a principal's beliefs and values regarding science and mathematics inform his or her decisions, yet little attention has been given on how a principal makes decisions regarding the teaching of mathematics and science, particularly at the lower grades. Even less is known about the impact of department heads or team leaders in high schools and middle schools on the science and mathematics curriculum. Support of these two groups may have long term impact on the success of school science and mathematics programs. We don't know enough about these leaders and their contribution to the success of mathematics and science programs.

Finally, please consider supporting projects that incorporate the use of resources and expertise from a variety of institutions. We have not tapped the resources available to us, but collaboration such as described in the Deans leadership model or IT Academy is difficult and time-consuming work. Support for inventive collaborations can make the sum greater than the parts for teachers and children. There are many equally beneficial program collaborations among schools, universities and businesses that can be explored for the improvement of teaching and learning. There is a rich and promising future for collaboration in science and mathematics education. It will be only limited by our imagination.

Thank you again for your time and interest.

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ABSTRACT

Developing high quality science and mathematics education programs for all students involves the integration of high standards, increased opportunities for study, inventive and substantial financial support for teacher candidates and collaboration among schools, university, businesses and non-profit organizations. This testimony draws on findings from practical problem-solving strategies and thoughtful, research-based efforts developed by faculty at University of Maryland Baltimore County's (UMBC) and others for use in creative successful teacher preparation programs.

The faculty of the Education Department assures the program's graduates are well prepared for the classroom by requiring all teacher education graduates to obtain a degree with a major in the subject area to be taught, plus the study of teaching and on-going field experiences. UMBC's teacher candidates participate in a 100-day internship in a partnership school prior to their graduation or certification. In support of these high demands the university has developed linkages with school districts, community colleges, nonprofit organizations and businesses to provide financial and programmatic support for the teachers. Future interests include the department's expansion into ecology studies, linkages with engineering and the integration of literacy with science.

BIOGRAPHY FOR EUGENE CARL SCHAFFER

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EDUCATION

Ed.D. Curriculum and Instruction, Temple University, Philadelphia, Pennsylvania, 1975.
M.Ed. English Education, Temple University, 1971.
B.A. English, Temple University, Minors: History and Economics, 1968.

CERTIFICATION

State of North Carolina Level G Licensure
Endorsements: Secondary English, Secondary Social Studies, Gifted and Talented Education, Teaching English as a Second Language

PROFESSIONAL EXPERIENCE

Chair and Professor, University of Maryland–Baltimore County, Baltimore, Maryland (2000-present)

Administer a 21 full-time member faculty who offer a range of undergraduate and graduate programs in education and related fields. Recently accredited by NCATE, the Department certifies undergraduates majoring in the Arts, Humanities, Social Sciences, and Natural Sciences graduate programs in English to speakers of other languages (ESOL) and bilingual education prepare graduate students for teaching English as a foreign language and curriculum development in K–16 venues in the US and abroad. The Department is a lead collaborator in the newly established interdisciplinary Ph.D Program in Language, Literacy, and Culture. The Training Systems graduate program targets business and industry with tracks in distance learning computer-based instruction, and instructional systems development. Responsibilities include decisions regarding tenure, promotion and merit, scheduling, budget, admission and advisement of, and assignment of faculty teaching and research activities.

Professor/Associate/Assistant Professor, The University of North Carolina at Charlotte, Charlotte, North Carolina (1976–2000)

Instruct at the undergraduate, master's, and advanced graduate level in research, evaluation, analysis of teacher behavior, models of teaching, and social studies methods, supervise student teachers and graduate interns; conduct research on school effectiveness, mentoring, analysis of teacher behavior and Asian education. Tenured, 1983.

Chair of the Department of Middle, Secondary and K–12 Education, The University of North Carolina at Charlotte, Charlotte, North Carolina (1996–2000)

Established and administered an 11 FTE member faculty unit who teach courses in middle grades, secondary and foreign language education; teaching English as a second language; and arts education. Responsibilities include liaison with all Departments in the College of Arts and Sciences. Decisions related to appointment, reappointment, tenure and promotion and budget

Chair of the Department of Curriculum and Instruction, (1993–1996)

Administered a 21 FTE member faculty unit who teach undergraduate and graduate courses in elementary, middle grades and secondary education. Responsibilities included decisions regarding tenure, promotion and merit, scheduling, admission and advisement of undergraduate students, and assignment of faculty teaching and research activities. (Management of a 1.1 million dollar budget)

Fulbright Scholar, Associate Professor, National Kaohsiung Normal University, Kaohsiung, Taiwan (1979–1981)

Instructed in evaluation, analysis of teacher behavior, gifted education and English as a second language; conducted research in analysis of teacher behavior and gifted education; and advised the Ministry of Education on gifted education.

Assistant Professor of Education and Coordinator of Student Teaching, Valparaiso University, Valparaiso, Indiana (1974–1976)

Taught social studies, language arts (graduate program), principles of elementary education, principles of secondary education, introduction to education, and supervised student teachers. Coordinated field experiences for pre-service education; directed a teacher center, and served as liaison for University School Relations.

Program Analyst, Humanities, East Windsor Regional School District, Highstown, New Jersey (1973–1974)

Implemented district-wide testing and evaluation; consulted on the development of social studies and arts curriculums, and developed an evaluation of the Special Education Program.

Teacher, Ashbourne School, Elkins Park, Pennsylvania (1968–1970)

Instructed junior high school age students in English and social studies.

Language Arts Instructor, Philadelphia Housing Authority, Philadelphia, Pennsylvania (Summer, 1968)

Taught language arts for students from six to twelve years of age.

SCHOLARSHIP (Recent)

Reynolds, D., Teddlie, C., Creemers, B., Stringfield, S., & Schaffer, E. (In press, 2001). *World Class Schools.* London: Rutledge.

Schaffer, E., Nesselrodt, P., Stringfield, S. (1997). *Impediments to reform: An analysis of destabilizing issues in ten promising programs.* Educational Research Service.

Reynolds, D., Creemers, B., Nesselrodt, P.S., Schaffer, E.C., Stringfield, S., & Teddlie, C. (1994). *Advances in school effectiveness research and practice.* Oxford: Pergamon Press.

Nesselrodt, P., & Schaffer, E. (1999). *A Song of Faith. . .A Song of Hope: Nathan Goldblatt School.* Journal of Education for Students Placed at Risk 4(4), 361–377.

Propst, K., & Schaffer, E. (1999). *The Mentor Checklists: A strategy for middle school mentors.* The NCASA Journal 28–36.

Propst, K., Schaffer, E., Bauguess, T. (Spring, 1998). *Effective Mentoring: The Principal's Role* NCASA Leadership, 32–37.

GRANTS (Recent)

Schaffer, E. and Propst, K. (1998–1999). *M.E.N.T.O.R. Project.* Funded by North Carolina State Department of Public Instruction.

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April 30, 2001

Chairman Sherwood L.Boehlert
House of Representatives
Washington, D.C.

Dear Chairman Boehlert:

Under the Rules of the House of Representatives, I am informing you that I am not receiving any Federal Government funding which directly supports the subject matter on which I am testifying before the Subcommittee on Research of the Committee on Science.

Sincerely yours,

Eugene C. Schaffer

Eugene C. Schaffer
Professor and Chair

Chairman SMITH. Thank you, Dr. Schaffer. Mr. Garner.

STATEMENT OF DAVID GARNER, PROJECT DIRECTOR, OKLAHOMA CITY PUBLIC SCHOOLS, URBAN SYSTEMIC PROGRAM

Mr. GARNER. First I would like to start out by saying that my comments, although some of them are harsh, are coming from the people in the trenches actually trying to implement reform in the classroom and teach children in the classroom. Over the last few days I have contacted several teachers throughout the State of Oklahoma, a couple in other states, and tried to get input from the people actually in the field.

First, I commend this Committee and President Bush for its mission to improve math and science education and leave no child behind. This is a very important and vital mission that can be accomplished with a focus on the key element to any school reform, that being the teachers.

As you can see in my written testimony Oklahoma City Public Schools has seen true benefits from the Oklahoma Teacher Education Collaborative funded by the National Science Foundation. This program was successful in addressing its goal of improving math and science teacher development at the university level. However, the program did not provide adequate support to achieve true, sustainable reform.

Unfortunately, inadequate support and non-systemic reform efforts are apparently the norm in public education. Partnerships and other K–12 reform efforts must focus on the teacher as the catalyst for change. If we are to focus on leaving no child behind, then we cannot continue to leave our teachers behind. This includes teachers in specialty areas such as ESL and special education teachers who are expected to teach children math and science but have little or no background in those fields.

Major obstacles the education profession faces each day in the attempt to support our teachers are the limited time and resources available to us. Many reform efforts such as OTEC have outstanding goals and intentions but are not funded at a level sufficient to address real reform. In addition, many other reform efforts focus on limited, non-effective professional development and packaged education programs that have little or no impact on student learning at the classroom level.

A 4-year teacher preparation program with very limited field experience is not adequate support. We must analyze and reform the teacher preparation programs and develop partnerships between universities and K–12 districts with input at the K–12 level that are specifically designed to provide continuous, professional growth opportunities for our teachers. Teachers must, just as doctors, lawyers, and many other professionals, be exposed to constant professional growth opportunities. Just as considered in many professions teachers must enter a practice when leaving their undergraduate program. We can no longer expect 4 years of preparation to be adequate. Reform efforts must focus on providing more training, resources, support, and research as the classroom level to make sure those training efforts are effective at the classroom level.

This will require expanding the windows of opportunity for professional development for all teachers and adequate resources to

support quality research-based opportunities. The National Science Foundation recommends a minimum of 60 hours of concentrated quality professional training to result in improvements at the student level. Teachers must be prepared in science, in math content, effective practices for teaching, and have a much deeper understanding of standards-based instruction to successfully prepare our students. Yet most reform efforts do not accomplish these tasks.

Funding opportunities must provide sufficient resources for true reform to take place. Inadequate training and support, whether it be through partnerships or any reform effort, must not be acceptable.

I encourage this Committee to focus on providing for real systemic change and support the NSF. That is all.

[The prepared statement of Mr. David Garner follows:]

PREPARED STATEMENT OF DAVID GARNER

The following bulleted items are the focus of my testimony to the Committee based on my professional experiences and observations as a science teacher and K–12 education reform administrator:

1. What partnerships have been most productive in fostering improved teacher preparation, teacher enhancement and curricular improvement and what were the key elements that made those partnerships so successful?
   - The Oklahoma Teacher Education Collaborative (OTEC) was funded by the National Science Foundation to improve teacher preparation at the university level and to benefit classroom teachers through professional development opportunities. This program originated at Tulsa University with my primary contact being the Master Teacher in Residence at the University of Central Oklahoma. Master Teachers in Residence are experienced K–12 classroom math and science teachers who have completed significant additional training to help prepare other teachers. Our Master Teachers worked at the university to assist in the preparation of new teachers. The goals of the OTEC program include providing innovative methods of recruiting teachers, reforming undergraduate curriculum for teacher preparation, and increased retention of new teachers in their initial years in the classroom.
   - Oklahoma City Public Schools benefited from OTEC through training provided to our district math teachers and through the partnership established with Oklahoma City Public Schools and the School of Math and Science at the University of Central Oklahoma. The School of Math and Science, which is separate from the School of Education at UCO, provides coursework in the math and science content areas while students complete their education theory coursework within the School of Education. OTEC's presence at UCO has had a impact on how math and science teachers are prepared in both mathematics content and teaching methods. This has improved at UCO over the past four years.
   - This partnership made progress towards improving teacher preparations in math and science at UCO as well as provide in-service and expertise at the K–12 level.
   - Unfortunately, however, the partnership did not accomplish reform within the School of Education at UCO as needed. The School of Education continues to produce teachers who are not adequately prepared to enter the urban school classroom. This is due, in my experience in working with new teachers, to the limited amount of coursework and field experiences at the university level. In short, the teachers are not gaining the experience needed within a four-year degree program. Therefore, the continued partnership between K–12 districts and universities is vital to supporting the teachers after their undergraduate experience.
2. Based on your experiences with partnerships involving institutions of higher education and/or industry, what are the major barriers to full implementation that should be considered in developing partnership programs? How can we ensure that partnerships meet the different needs of classroom teachers, school administrators, district administrators and policymakers?

- Based on my experience, the major barrier to full implementation involves the lack of time and resources devoted to true collaborations between the K–12 and university entities.
- In education, time is the most valuable and limited resource in preparing our teachers. When partnerships are formed, the time issue is always a factor.
- Partnerships must have realistic goals and expectations and must provide adequate resources and schedule modifications so that teachers can participate filly in effective professional development programs. Too many reform efforts focus on short-time professional development activities that have little or no significant impact on classroom instruction. Effective professional development must be supported at a level in which adequate training can be followed up with significant classroom experiences, coaching, mentoring, and true research to provide evidence of effectiveness. Unfortunately, many partnerships and other reform efforts are not supported at the appropriate level to accomplish high-quality reform for the children.

3. It is one thing to develop a model program and yet another to implement this model in a district- or state-wide effort. How can funding opportunities best be structured to facilitate fill implementation of model programs so that they have the breadth necessary to achieve true reform?
   - Again, we must address the time issue. True systemic reform, at the university or K–12 level, takes time to develop. In addition, we have very limited time to access teachers, administrators, and undergraduate students to impact the change.
   - Partnerships, as well as other reform efforts, must address the following restrictions:
     - It is very evident that the amount of knowledge and experience that entry year teachers have when they enter the classroom for the first time is not adequate. Reform efforts must discover ways in which to improve teacher training programs as well as provide additional field experiences. Specifically, partnerships between K–12 districts and universities must focus on supporting teachers at the classroom level after they leave their undergraduate experience. We cannot continue to send teachers into the classroom with limited support and resources to serve our children.
     - Due to the limits on how much "time" we can expect our teacher prospects to spend in college, we must adopt a nationwide approach to promoting respect for the education profession.

Which brings my testimony to a closing statement:

Teachers must, just as doctors, lawyers, and many other professions, be exposed to constant professional growth opportunities. Just as considered in many professions, teachers must enter a "practice" when leaving their undergraduate program. We can no longer expect four years of preparation to be adequate! Reform efforts must focus on providing more training, resources, support, and research at the classroom level. This will require expanding the windows of opportunity for professional development for all teachers and adequate resources to support quality research-based opportunities. The National Science Foundation recommends a minimum of 60 hours of concentrated quality professional training to result in improvements at the student level. Teachers must be prepared in science and math content, effective practices, and have a much deeper understanding of standards-based instruction to successfully prepare our students. Yet, most reform efforts do not accomplish this task. Funding opportunities must provide sufficient resources for true reform to take place. Inadequate training and support, whether it be through partnerships or any reform effort, must not be acceptable. I encourage this Committee to focus on providing for real systemic change for our children!

BIOGRAPHY FOR DAVID GARNER

David Garner is a professional educator who currently holds the position of Project Director of Oklahoma City Public Schools' Urban Systemic Program funded by the National Science Foundation. Mr. Garner is the co-author and primary researcher of the district's Urban Systemic Program proposal to the National Science Foundation. Prior to entering the Curriculum and Instruction Department as a math and science curriculum administrator three years ago, Mr. Garner served as a middle school science teacher and coordinated a comprehensive after school program for at-risk students in Oklahoma City Public Schools. Mr. Garner received the Teacher of the Year award in his second year as a teacher at F.D. Moon Middle School.

The Honorable Sherwood Boehlert, Chairman
U.S. House of Representatives
Committee on Science
B-374 Rayburn House Office Building
Washington, D.C. 20515

Re: Letter of Disclosure

Oklahoma City Public Schools is currently a recipient of an Urban Systemic Program grant from the National Science Foundation. The title of the grant is: An Exciting "ERA" for Change: Eliminating Random Arrows. The purpose of the Urban Systemic award is to stimulate dramatic improvement in the quality of teaching and learning for all students; the development of standards based mathematics, science and technology curriculum and improved alignment, both vertically and horizontally; and the use of continuous instructional improvement strategies in the classroom.

David Garner

David Garner
Project Director, Oklahoma City Public Schools Urban Systemic Program

Chairman SMITH. Mr. Garner, you must have been a great teacher. You did it under 5 minutes.

Mr. GARNER. And the first one.

Chairman SMITH. Dr. Parravano.

Mr. GARNER. A lot of practice.

Chairman SMITH. Thank you. Dr. Parravano.

STATEMENT OF DR. CARLO PARRAVANO, EXECUTIVE DIRECTOR, MERCK INSTITUTE FOR SCIENCE EDUCATION

Dr. PARRAVANO. Chairman Smith, Congresswoman Johnson, and distinguished members of the Subcommittee. Thank you for this opportunity to comment on the role of school business partnerships and improving math and science education.

Merck has a long and proud history of corporate support for education. Long before partnerships became popular Merck contributed grants, gifts, and the talent of its employees to the improvement of science education. These efforts, while generous, were limited in scope and were not guided by specific goals. In 1993 Merck, motivated by a deep concern about the quality of science instruction and a desire for a more strategic approach to education reform, created the Merck Institute for Science Education.

The goal of the Institute was to raise the levels of student participation and performance in science so that all children could meet rigorous national and state standards. Recognizing the scope of this challenge the company's commitment to the Institute was long-term.

Why has Merck made this serious commitment? In the words of Merck Chairman, Raymond Gilmartin, because science education is the lifeline of our business. Merck's success is built on innovative research and development requiring scientists of the highest caliber whose interest in the natural world was stimulated at an early age and was sustained and developed throughout life.

The Institute is guided by a vision of high quality instruction in which guided inquiry is a regular part of the classroom experience of all students. In this way science teaching and learning parallel the methods used by scientists to understand the natural world.

Our strategy at the Institute is to simultaneously work in four different areas. First, to enhance teachers' knowledge and skills, second, to provide good instructional materials, third, to build strong, professional communities across and within schools, and fourth, to create local, state, and national policy environments that support our vision.

According to our external evaluators from the Consortium for Policy Research in Education our work is taking hold. First, science has become our priority in our school districts. There is a standards-based curriculum in place, and district leaders are actively supporting its implementation. Second, we have learned how to provide high quality, professional development and to do so at considerable scale. And third, the bottom line, the improvement of student performance. Analyses of student performance on standardized tests reveal that students who have received science instruction over several years from teachers who have participated in the professional development outperform students who have been

taught by non-participants. We have learned important lessons from our experience.

First, if you build good professional development programs and they are seen as worthwhile, teachers will come voluntarily. Second, better assessment tools in science are needed. Although teachers are seeing improved student work in their classrooms, the available assessment measures do not adequately demonstrate this change. Third, the state policy context can play a pivotal role in stimulating instructional reform. And fourth, we have learned that this work is very hard to sustain, it is messy, and it isn't for the faint-hearted or easily-winded.

There are certain key elements of our programs that we believe are critical to our success. They are a long-term commitment, a sharp and unwavering focus, an emphasis on building capacity, and the constant attention to evaluation and benchmarking of results. Above all, Merck's corporate reputation for high-quality scientific work and high ethical standards brings credibility to our work.

As noted author Seymour Sarason has written, the failure of educational reform is the failure to touch deeply and profoundly the entrenched culture of schools. Thus, despite the millions of dollars poured into changing schools and the endless hours educators have devoted to adopting new practices, the educational landscape in this country remains largely unfazed.

The Merck Institute for Science Education has demonstrated its ability to row against this stubborn current. Science education in our partner school districts is no longer in the wings. It occupies center stage as an emotionally-engaging and intellectually-challenging experience for students. Thank you very much.

[The prepared statement of Dr. Carlo Parravano follows:]

PREPARED STATEMENT OF DR. CARLO PARRAVANO

BACKGROUND

In 1983, the National Commission on Excellence in Education released its scathing report entitled *A Nation at Risk.* In the introduction, the Commission wrote, "We report to the American people that while we can take justifiable pride in what our schools and colleges have historically accomplished and contributed to the United States and the well-being of its people, the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a nation and a people." In particular, the report detailed the steady decline in science achievement scores by U.S. high school students.

More recently, the National Commission on Mathematics and Science Teaching for the 21st Century—the Glenn Commission—underscored the urgency for education reform in its report to the nation entitled "Before It's Too Late." In the commission's words, "our students' performance in mathematics and science is unacceptable."

To address these issues, schools and businesses have been entering into partnerships with increasing frequency over the past two decades. Many companies have become involved with schools in increasingly complex ways, moving from their initial instincts to provide materials and money, or to "adopt" schools, toward more lasting and comprehensive partnerships. These partnerships represent a substantial commitment on the part of American business to improve the quality of public education.

Departing from the more passive forms of business support common in the past, some corporate leaders are challenging schools to improve, and are willing to work with the schools to make improvement happen. To promote education reform, these leaders are sharing their expertise, resources, and their political capital. These school-business partners are setting high but achievable goals, working together to reform key elements of the school system, mobilizing community support for reform, and setting the agenda for education reform at the state and national levels.

This proactive approach is what Merck envisioned when its board created the Merck Institute for Science Education in 1993. A year earlier, Merck had undertaken an in-depth study of the problems related to student performance and participation in science before making a long-term commitment to address this issue. Based on the results of the study, corporate leadership decided to focus resources on science education in grades K–8. The Merck Institute's charge was to collaborate with teachers, administrators, parents, community members, and Merck employees to improve the teaching and learning of science, beginning in local schools.

And why does Merck feel this is so important? In the words of Merck Chairman Raymond V. Gilmartin, "Merck has made a serious commitment to improving science education because it is the lifeline of our business. Merck's success is built on innovative scientific research and development, requiring scientists of the highest caliber whose interest in the natural world was stimulated at an early age and was sustained and developed throughout life."

THE MERCK INSTITUTE FOR SCIENCE EDUCATION

The Merck Institute's overall goal is to raise the levels of participation and performance in science for all students in kindergarten through 8th grade. The Institute began its work by establishing a partnership with four public school districts: Linden, Rahway, and Readington Township in New Jersey, and North Penn in Pennsylvania. These sites were chosen because Merck has major facilities in or near these communities.

The Institute is guided by a vision of high-quality instruction in which inquiry is a regular part of the classroom experience of all students. In other words, science teaching and learning parallel the methods used by scientists to understand the natural world. Student investigations of natural phenomena are at the heart of this approach, and the purpose of these investigations is to develop the skills and habits of mind that are central to scientific inquiry.

This type of instruction requires teachers to possess a relatively sophisticated knowledge of science and the teaching skills to guide and manage inquiry. In addition, teachers need long-term support in and outside of the classroom. Corresponding changes must be made in curriculum, instructional materials, assessment, professional development, resource allocation, and other district policies. To enact such changes, policymakers and administrators must give science greater priority, and they must be willing to invest more to provide teachers with the time, support, training, and materials required. Similarly, parents must learn about and support the new instructional approach. Only training teachers, however, is not sufficient; a systemic strategy is necessary to achieve such fundamental changes.

To achieve these changes, our strategy at the Institute is to simultaneously:

- Enhance teachers' knowledge and skills,
- Provide instructional materials to support reform,
- Build strong professional communities within and across schools, and
- Create local, state, and national policy environments that support this vision.

MEASURING RESULTS

In 1992, even before the official launch of the Institute, we engaged the services of the Consortium for Policy Research in Education (CPRE) at the University of Pennsylvania to conduct a long-term evaluation of our work. Each year, CPRE assesses the progress of the Institute using a range of measurable criteria: student performance and course selection; quality of professional development; and changes in classroom teaching, school culture, and district policy. Institute programs are continually modified in response to CPRE's recommendations, the considerations of the Institute's national advisory board, and feedback from teachers and administrators in the partner school districts.

The different roles, perspectives, and resources that businesses can bring to the task of education reform are important, but ultimately results are what really matter. Past the midpoint of this 10-year initiative, CPRE is reporting that our work is taking hold. The year 2000 annual evaluation report states:

- First, the Merck Institute's systemic approach has worked. Science has become a priority in the partner districts. There is an inquiry-centered curriculum in place, and district leaders are actively supporting its implementation. The districts have made changes in policy, organization, and assignments in support of our vision of science instruction.
- Second, the Institute and its partners have not only learned how to provide high-quality professional development, they have learned how to provide it at

considerable scale, and they have learned how to attract high proportions of teachers to participate.

- Third, participation matters. The more professional development teachers receive, the more their classroom instruction resembles the vision of good practice advanced by the Institute.
- Fourth, it appears that when a critical mass of teachers in a school has received professional development and begun to change their practice, the practice of non-participants also begins to shift in the same direction.
- Fifth, the strategy of using teams of leader teachers to stimulate instructional change across the classrooms of their schools has been a mixed success, as it is highly dependent on the support of the principal and the careful selection of leader teachers.
- Sixth, the districts have become increasingly active in promoting the Institute's vision instructional reform. District staffs are now more attentive to how their policies and procedures affect progress. The strategic planning process seems to have fostered increased understanding and commitment among central office staff. There are signs that the partner districts have internalized some key lessons drawn from this experience and, within their resource limitations, are applying what they have learned in language arts and mathematics.
- Seventh, all of this has been made easier because Merck's reputation, expertise, and commitment to public education have enabled the Institute to influence state policy and create an environment more supportive of the reforms.

The eighth and final conclusion concerns the bottom line—the improvement of student performance. Analyses of student performance on standardized tests reveal that students who have received science instruction over several years from teachers who have participated in the partnership professional development outperform students who have been taught by non-participants. These data suggest that, in the long run, as more and more teachers participate in the workshops, there will be a positive and significant impact on student performance in science.

LESSONS LEARNED, LESSONS CONFIRMED

In the course of our work with partner school districts and beyond, the following lessons have become clear:

- If you build good professional development programs, teachers will come. We have learned that they will voluntarily take advantage of opportunities to learn and to improve their teaching practice—if the opportunities are seen as worthwhile. Respect for teachers' professionalism, expertise, and experience results in a growing commitment by teachers to improvement.
- Better assessment tools in science are needed. Existing measures do not adequately show the effects of better science instruction. Right now, teachers see improved student work in their classrooms and a higher level of student interest in science, but the available measures do not adequately demonstrate this change to parents, school leaders, or the public. In addition to assessments that provide good diagnostic information for teachers' instructional planning, we need assessments that are persuasive to the public and policymakers as well.
- Teachers' knowledge and skills are critical factors in the classroom learning experience, but not the only ones. Good curriculum materials are also essential. Teachers need access to and support in implementing standards-based curricula and teaching materials. They need the support and knowledgeable involvement of school and district-level administration, parents, and the community. The Institute addresses these needs through resource centers featuring exemplary science education materials, Merck employee volunteer programs, and parent involvement programs, in addition to its support of long-tern professional development.
- The state policy context on incentives for change can play a pivotal role in stimulating instructional reform, and the Institute's role in shaping state policy has had a high payoff.

KEY ELEMENTS OF SUCCESS

There are certain salient features of the Institute's programs that we believe are critical to our success:

- *Corporate reputation.* Merck's corporate reputation for high-quality scientific work and high ethical standards brings credibility to the Merck Institute's

work in science education. Merck's corporate image and record of success have enabled us to raise difficult issues and to push hard for change.

- *Long-term commitment.* Significant changes in the classroom require a long-term, sustained effort on the part of corporations involved in education reform. Increased teacher mobility, high turnover in administrative personnel, and changes in district priorities and policies threaten the reforms that have been accomplished. Scaling up is difficult because of the intensity of the work and the long timeframe for institutionalizing it. Persistence and patience pay off.
- *Maintaining focus.* The Institute's core capabilities include providing high-quality technical assistance to teachers, maintaining constructive and collaborative relationships with partner school districts, addressing systemic issues that influence curriculum and instruction, aligning desired changes with state and national standards, and accepting accountability for its efforts. These strengths represent the Institute's focus, and just as the most effective corporations rarely stray from their core mission, so too does the Merck Institute believe that maintaining its focus is critical to success.
- *Capacity-building.* Rather than *do* for the school districts or *give* to the school districts, we look for ways to help them use available resources to improve and then to build upon these successes. Of course, we provide some funding and a great deal of technical assistance—but always with the consideration of how school leaders may sustain and institutionalize the changes we have helped to effect. When teachers train other teachers—and support and advocate for the reform efforts—local capacity is increased.
- *Leveraging resources.* We leverage resources and encourage our school district partners to do likewise. We help link them to regional and national sources of expertise in science education, including the National Science Foundation. In 1996, NSF awarded the Institute and its partner districts a $2.4M, five-year award to extend and intensify its programs for teachers. In addition to the monetary benefits, this award also serves to provide external validation of the quality of our programs.
- *Evaluation and benchmarking of results.* CPRE assesses the progress of the Institute through measurable criteria on an ongoing basis. Each year, after receiving feedback from CPRE and others, we revise our strategies to work more effectively within a changing landscape.

Larry Cuban, former school administrator and reform expert, noting the infuriatingly meager impact of two decades of educational reform, concludes: "When all is said and done, more is said than done." His argument is that most reform has been superficial rather than substantive, a rhetorical factor in school district central offices, state departments of education, and in various legislatures without having meaningful influence in the classroom.

Noted author Seymour Sarason agrees: The failure of educational reform is the failure to touch deeply and profoundly the entrenched culture of schools. Thus, despite the millions of dollars poured into changing schools and the endless hours educators have devoted to adopting and adapting new practices, the fact is that the educational landscape in this country remains largely unfazed.

The Merck Institute for Science Education has demonstrated its ability to row against this stubborn current. Science education in our partner school districts is no longer in the wings; instead it occupies center stage, as an emotionally engaging and intellectually challenging experience for students. Based on the lessons we have learned about education reform and the power of collaboration, we will continue to build partnerships to improve student performance and participation in science until high-quality science education is indeed the standard for *all* children.

BIOGRAPHY FOR CARLO PARRAVANO

Present Position:

Executive Director, Merck Institute for Science Education, P.O. Box 2000, Rahway, NJ 07065; (732) 594–7401.

Education:

B.A. in Chemistry, June 1967, Oberlin College
Ph.D. in Chemistry, June 1974, University of California at Santa Cruz
Thesis: A Crossed Molecular Beam and Tunable Laser Apparatus Applied to Reactive Scattering Studies

Employment:

1989–1992 Chair, Division of Natural Sciences, SUNY Purchase
1985–1992 Director, Center for Mathematics & Science Education, SUNY Purchase
1974–1992 Assistant Professor to Professor of Chemistry, SUNY Purchase
Taught courses in general, physical, instrumental and environmental chemistry

Research:

Molecular beam studies of collisions of excited atoms and molecules, the application of nuclear magnetic resonance and chromatography techniques, and environmental monitoring and analysis.

Awards/Fellowships:

1999 Elected to rank of AAAS Fellow
1997 New Jersey Science Teachers Association Atkins Award
1996 New Jersey Business/Industry Science Education Consortium Distinguished Service Award
1993 New Jersey Science Supervisors Association Outstanding Educator Award
1989 Chemistry Teachers Club of New York Oscar Riker Foster Award
1989 Science Teachers Association of New York State Distinguished Service Award
1977 SUNY Chancellor's Award for Excellence in Teaching
1970 National Defense Education Act Predoctoral Fellow (1970–1974)

Recent Grants Awarded (selected):

1999 National Science Foundation for Penn-Merck Collaborative for the Enhancement of Science Education ($1,619,975 for five years)
1998 National Science Foundation for New Jersey Statewide Systemic Initiative ($5,800,000 for five years)
1996 National Science Foundation for The Partnership for Systemic Change: A School/Business Collaboration to Enhance Science, Mathematics and Technology Teaching and Learning ($2,400,000 for five years)
1993 National Science Foundation for Penn-Merck Collaborative for the Enhancement of Science Education ($1,800,000 for five years)
1992 DeWitt Wallace-Reader's Digest Fund for Science Leadership Institute for Elementary School Teachers ($1,047,200 for three years)

IBM Corp. for establishment of science and mathematics teaching computer facility in Division of Natural Sciences ($382,000)

Texaco Foundation for faculty and undergraduate research ($100,000)
1991 New York State Education Department for Science Leadership Institute for Elementary School Teachers ($45,000)
1990 New York State Legislative Initiative to fund program in secondary schools to deal with hazardous chemicals in the classroom ($200,000)

New York State Education Department for Institute for New Teachers of Regents Chemistry ($60,000), ($125,000 for two years)
1989 National Science Foundation for mathematics and science middle and secondary school teacher institutes, and research opportunities for teachers in industrial laboratories ($285,000 for three years)

New York State Education Department for statewide replication of secondary school teacher institutes ($428,000 for three years)

New York Power Authority for teacher institute on Science, Technology and Society ($112,000 for three years)

New York State Education Department for Science and Technology Entry Program for minority and disadvantaged students in grades 6–12 ($247,000 for three years)

Publications:

Parravano, C. "The School-Business Partnership: What Can It Offer?" *ENC Focus,* 7 (January, 2001), accepted for publication.

Parravano, C. "The Road Ahead for Professional Development," *Explorer,* Merck Institute For Science Education, 1, 5 (Fall, 1999).

Parravano, C. "Teachers Hold the Key to Better Learning," *Explorer,* Merck Institute for Science Education, 1, 3 (Spring, 1999).

Committee on Developing the Capacity for Selecting Effective Instructional Materials, National Research Council, *Selecting Instructional Materials: A Guide for K–12 Science,* National Academy Press (1999).

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Studebaker, J.F., Parravano, C., Yang, H.S., "The Study of Disulfide Bond Pairing in Proteins and Fragments with HPLC," *Biological/Biomedical Applications of Liquid Chromatography,* Hawk, G., Editor, Marcel Dekker, 1978.

Anderson, R.W., Goddard, T.P., Parravano, C., Warner, J., "A Crossed Molecular Beam-Tunable Laser Determination of the Velocity Dependence of Intramultiplet Mixing: $K(4p^2p\ 1/2)+He$ to form $K(4p^2p\ 3/2)+He^*$." *J. Chem. Phys.,* 64, 4037 (1976).

Sykes, B.D., Parravano, C., "A Nuclear Magnetic Resonance Study of the Inhibition of Lysozyme by N-Acetyl-D-Glucosamine and Di-N-acetyl-D-glucosamine," *J. Biol. Chem.,* 244, 3900 (1969).

Parravano, C., Baldeschwieler, J.D., Boudart, M., "Diffusion of Water in Zeolites," *Science,* 155, 1535 (1967).

Professional Activities:

Director to Executive Director, Merck Institute for Science Education, 1992-present. Responsible for planning, development and implementation of all corporate initiatives in pre-college education.

Co-Principal Investigator, Site Director and Co-chair, Executive Board, 1992-present. New Jersey Statewide Systemic Initiative.

Vice-Chair, New Jersey Professional Teaching Standards Board, 1999-present.

Co-Chair, New Jersey Science Core Curriculum Standards and Framework Groups, 1995-present.

Organized in collaboration with the National Science Foundation Principal Investigator Annual Meeting for Local Systemic Change projects, 1998-present.

Assisted in organizing and hosted National Science Resources Center conference "Corporate America's Impact on Elementary Education," September, 1994, Whitehouse Station, NJ.

Member, Advisory Boards: National Science Resources Center; LASER (Leadership Assistance for Science Education Reform); Biological Sciences Curriculum Study; Eisenhower National Clearinghouse for Mathematics and Science Education; New Jersey Business Coalition for Educational Excellence; Education Law Center; Liberty Science Center; New Jersey Mathematics Coalition; FANS project (Families Achieving the National Standards); Beckman@Science; Douglass Project for Rutgers Women in Math, Science and Engineering.

Member, Editorial Advisory Board: *ChemMatters* (1994–1997); *ChemComm* (1996–present); *SciTeks* (1997–1999) (American Chemical Society curriculum materials).

Invited presenter, New Jersey Business/Education Summit meetings, November, 1996 and 1997.

Invited presenter, U.S. House Committee on Science, May, 1997.

Invited participant and presenter, Executive Office of the President, Office of Science and Technology Policy, national forum, "Making It Happen: First in the World in Science and Math Education," July, 1995.

Selected to join panel with U.S. Secretary of Education, NJ Governor, NJ Commissioner of Education in a televised conference announcing statewide effort to establish core curriculum standards, February, 1995.

Deliver workshops and programs for elementary and secondary school teachers, and K–12 classes and science clubs.

Deliver presentations to business, parent and community groups, professional societies, school boards and legislators on science education reform.

Advise corporations, foundations and informal science centers on science education reform initiatives.

Professional Affiliations:

American Chemical Society and the Division of Chemical Education
National Science Teachers Association
Association for Supervision and Curriculum Development

American Association for the Advancement of Science
New Jersey Science Teachers Association
New Jersey Science Leaders Association

Merck Institute for Science Education

Carlo Parravano, Ph.D.
Executive Director

April 30, 2001

Honorable Sherwood L. Boehlert
Chairman
Committee on Science
United States House of Representatives
2320 Rayburn House Office Building
Washington, DC 20515

Dear Mr. Chairman:

Please be advised that a portion of the work described in my testimony has been supported by the National Science Foundation's Local Systemic Change program (Grant No. ESI 9696220). The project title is *The Partnership for Systemic Change: A School/Business Collaboration to Enhance Science, Mathematics and Technology Teaching and Learning.*

Sincerely,

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Doc. # 1004666

Chairman SMITH. Thank you, Mr. Parravano. I will start with the 5-minute rounds, and then we will move through. If we have enough time, we will maybe even consider a second round.

In terms of partnershipping there is a great deal of evidence that suggests that the interest and ability of a student is somewhat determined by their home life, their parents. Have we—is there any suggestions, ideas, effort out there to involve parents and maybe the bottom-line question is should this be part of our quest in terms of where we go with this project and how it is conducted? Anybody give me a thought on an effort to involve parents in terms of—yes. Mr. Sadler. Dr. Sadler.

Dr. SADLER. Well, one of the methods that we found to be useful is in our curriculum work we have a number of homework assignments where students actually interview their parents, asking them questions or do some particular activity with the parents to involve the parents in whatever science the kids are studying. That seems to be highly popular, especially if the students end up knowing something that their parents don't.

Chairman SMITH. Is it—do you think it would be true? Is there a direct relationship toward the interest and the ability in the effort and interest that those kids might have in science and math in relation to their—the parents' concern, fear of how they did in math and science? Is that something that we should be looking at or——

Dr. SADLER. In studies that we have done there is certainly a relationship between the educational level or science education level of the parents and how well kids do in school.

Chairman SMITH. Dr. Parravano.

Dr. PARRAVANO. Yeah.

Chairman SMITH. You have a comment.

Dr. PARRAVANO. I was just going to add that we feel that that is a very, very critical area, and in fact, part of our professional development experiences with teachers includes working with them on how to involve parents. Parents can be very, very supportive of their child's education. We actually have family science nights, regularly organized nights where teachers invite parents to come in and actually work on the same curriculum materials that the students are working on. And we try to make that connection between school work and home as strong as possible. The area that I would suggest that needs the greater amount of work is in the middle school. There is less connection than one might like.

Chairman SMITH. And maybe that leads to my next question, and I will start with you, Mr. Garner, on the next question. And that is do—what is the state of research or your personal experience at what grade levels does the first interest or excitement generate in math and science that tends to be carried through?

Mr. GARNER. We find the students that establish that interest in the early grades, K through 2, do much better in the upper grades. As a middle school science teacher usually when I had students come to me with that initial interest, they gained that initial interest early on in the education process. We are finding that the drop-off where students start to lose interest is definitely at the middle school level. The parental issue, what Oklahoma City Schools is doing to combat that right now and get more parents involved in

that because we continuously get the comments from parents, well, I wasn't good in math or I wasn't good in science, so my child won't be. And we are establishing a partnership between the public library system to provide resources to help benefit the parents in helping their students with math and science.

Chairman SMITH. Well, Dr. Schaffer, what about if that is correct, at least to some extent, are we suggesting that the K through 5 teacher should have a degree in math and science if that is where the greatest stimulus comes from?

Dr. SCHAFFER. I don't know that that will always happen. I think——

Chairman SMITH. Probably not.

Dr. SCHAFFER. There are other strategies that may work just as well. I think two things are important that have been said already. One of which is people have to have confidence in science or in math skills, the teachers and the parents both. How do you get that? One way is to build a kind of confidence in inquiry, and I think a number of people have said here it is not just the content but a confidence in the inquiry. If you have teachers and parents who are interested in not, necessarily having the answers, but willing to play with the ideas I think is a very important thing. That also means that what we say to parents is—parents and teachers, not that you have to have all the answers but that you are willing to explore. And I think if you say to parents, you don't have to have the answers for your child's questions on science. Why don't you go explore with it? Take them to the library. We have something called the Children's Inquiry Conference that really deals with—it is an on-line process, and it was kind of an antidote to science fairs. The idea was not to demonstrate a particular outcome but rather a process by which you came to conclusions, and people just investigated topics. And that was a strategy for involving parents and also teachers who might feel less confident.

Chairman SMITH. We will move onto the Ranking Member Eddie Bernice Johnson. The bells means that we have 10 minutes left in this vote. We will go ahead with this next 5 minutes and then we will recess for a vote.

Ms. JOHNSON. Thank you, Mr. Chairman. It seems to me that the challenge is first attracting teachers and then keeping them. Where there is a partnership are teachers more likely to be more attracted to the classroom, and what is the retention like once they are more intricately involved with the workplace? Have you seen that it influences teachers any? Is it the paycheck?

Dr. SCHAFFER. If I may respond, the Maryland and actually North Carolina as well have a strong partnership model that involves both the K–12 schools and the universities and community colleges, and in many cases for strengthening teachers' performances and also their involvement in the schools are long-term involvements of a particular student teacher or a particular intern in that school for a year, sometimes 2 years. So there is first of all a kind of welcoming involvement at that level. Second of all, and I will turn to North Carolina having a particular strong model in mentoring their teachers. And I want to add two things to it that could make it even stronger.

Mentoring in the first year is really a great deal of "how do I survive?", "where is the men's room or the lady's room?", and "who knows the most about the school?", where the answer is the secretary and the janitor. And that is important first round but there is a second round which is questions such as, how do I teach photosynthesis? What is the best way to get to my kids? Then we start to get into a content mentoring process, and I think that is the more difficult one but if we are going to retain people, they have to feel successful in the job they are doing. And I think that is one thing that would—that comes from a successful mentoring model.

There is one more person involved that we tend to overlook in this process, and that is the principal and the administration of the school and the degree to which they are committed to particular programs. I happened to see a program on technology and on leading ed schools, and it was clear that the principal knew almost everything there was to know about what was going on in those classrooms and what was going on in science, and it was clear the teachers respected him and respected what was going on in the school. That is the kind of support that is hard to get and is often needed.

Mr. GARNER. And to second that with experience in Oklahoma City only 10 percent of our principals have a math and science background of any type, and we are experiencing many retention problems in teachers within the first 3 years. And at this time we don't have a partnership to combat that. What we need from the universities is more support for the teachers when they enter the classroom.

Dr. SADLER. Well, having been a middle school math and science teacher I can that the classrooms are very isolated in a very isolating place, and one thing that partnerships do is they help teachers move to leadership positions in their field. Lots of teachers who have engaged in our programs then join professional organizations, start to give workshops at conferences, and involve more stimulating curriculum materials in their classrooms. So it helps them see beyond the problems in their own classroom.

Dr. PARRAVANO. Yeah. And if I could just add that in addition to partnerships within a school building, let us say, partnerships external to the school or external to the district are also, I think, very, very useful and play an important role. School districts are somewhat notorious for having lots of leadership changes and lots of changes in priorities and so on. An external partner such as the Merck Institute can really serve as an anchor, can really serve to maintain a very sharp vision, a very sharp focus for teachers.

Ms. JOHNSON. How extensive are your partnerships with Merck? Do you primarily work with those schools that are located where you are located?

Dr. PARRAVANO. Yeah. What we decided was that in the initial period we were going to work with school districts that are located in areas where Merck has its major facilities. And the plan is to really work over a long term with these school districts, identify some of the key lessons, some of the key issues, and then replicate those efforts.

Ms. JOHNSON. Thank you.

Mr. EHLERS. Gentlemen, this time has expired. We have to go very shortly. There is not time for me to do 5 minutes of questioning but I am going to ask you a very short question which is going to take a very long answer. And so we won't expect the answer today but we would like to—I would like to have you put it in writing.

If you were sitting in my place as a Member of Congress and were developing a program to spend $200 million per year to improve the nation's elementary and secondary science programs, how would you spend that money?

The second question is exactly the same question except $500 million instead of $200 million. If you would take a look at that and send written response to the Committee for the record, I would very much appreciate that. And that—it may have much more relevance than you think it might have because that is exactly the question that we are facing right now. With that I will have to call a recess until we conclude our votes, and we will return. Committee stands in recess. The Subcommittee will reconvene

[Whereupon, the Subcommittee recessed, to reconvene the same day.]

Chairman SMITH [continuing]. Would call on Mr. Etheridge.

Mr. ETHERIDGE. Mr. Chairman, thank you, and I appreciate the testimony that each of you have given, especially yours, Mr. Garner——.

Mr. GARNER. Thank you.

Mr. ETHERIDGE [continuing]. Having been out there recently where the rubber meets the road as my wife reminds me when I go home with starting to agree with things and talking about what it is going to take to improve math and science education in this country.

Let me approach you from a little different viewpoint if I may, so you will understand where I am coming from rather than get to specific questions. I served as State Superintendent for the State of North Carolina for 8 years working very hard to improve math and science, a state that has had some success in a number of areas but as you have indicated we still have a long ways to go. I think we, as a nation, has no more important long-term tasks than to improve the technological literacy of our people through math and science and a number of other areas. Last week and again just this morning NASA Administrator, Dan Goldin, told this Committee that in the first quarter of this century America's economic success and standard of living will be driven by the integration of nano-technology, biotechnology, and information technology. Pretty big issues but they can't go anywhere unless we do what you have been talking about.

So that being said I think that is an extraordinary challenging statement when you think about how far we have to go, grow and go academically to get there in the next 25 years if we are going to make those opportunities a reality for the American people. But I really believe this transformation has already stated to taking place. We hear all the horror stories but I think it is taking place already. Right now more Americans make computers than make cars. More Americans make semiconductors than construction ma-

chinery. And more Americans spend their days processing data than refining petroleum. So we have made a step in that direction.

Our economic competitiveness, though, depend on our ability to upgrade the skills of our workers. Okay. Those in the public schools as well as those who are already out there because we have to import workers through the HB–1 VISA. You may not be familiar with that but a lot of folks are. Because Americans cannot domestically produce the kind of workers we need with the skill levels we need, and we are looking to the public schools and universities to get there as we look at this technologically-based demands that the industry has. And at the same time the digital divide is growing when we think about our African-American, Latino, and the rural people in this country. Whatever state you may be in, be it North Carolina, that rural divide is growing, and I think that is indispensable and economically it is unsustainable if we are going to get to where we need to get to as a country.

I know that is more of a statement than a question but I want to ask each of you if you will to comment. If the scale of the proposals that we are considering that you have talked about, each individually, are anywhere near the magnitude that they need to be to meet the kind of challenges that we are hearing. Because I think we are dealing with issues on the edges when the challenge is so much greater than where we are, and we aren't putting the resources behind what we need to put it behind to get to where we need to get to. It is easy to talk about a few dollars but I think this issue is far greater than what we are talking about, and I hope you will comment on that. Whoever wants to start.

Dr. SADLER. I can start. I agree with you that the problem is not just educating the elite but educating all the kids in the country. And the question about how big—what is the impact of this size program, a $200 million a year program, that is a lot of money to build models and test which ones work so that they can be ramped up and scaled up. But if you divide $200 million by the 50 million kids who are in K through 12, that is only $4 a kid, and that is probably not going to be enough to have the effect that you want to have. Even at $500 million.

Dr. SCHAFFER. I would add to that that one of the things that seems very critical to me was—has come up as the notion of collaboration. And what I see is getting everybody going in the same direction on some of these things so that you get a kind of synergy on the model, whether it is business, K–12 education, or higher education as three players in this partner. And I am actually going to use a North Carolina piece right here.

One of the things that amazed me about North Carolina's educational system has been the capacity to line up not just K–12 but all the way through the university system with enormous effort between the public, the State Department of Public Instruction and the university system, which probably produces 90 percent of the teachers, to have a collaborative, ongoing model that looks at this very directly and focuses on it. And then also delivers specific resources when needed like the science and math centers that are at six of the state universities in North Carolina. I think that kind of clear, state-focused model that seems to organize the entire state

in a direction is very powerful. In Maryland the redesign of education is one that probably comes as close to that as well.

So the—I think these kinds of collaborative models are critical to getting a large success and a long-term success.

Mr. GARNER. I believe in looking at the Federal funds coming into K–12 districts, particularly Oklahoma City Schools and the State of Oklahoma as a whole. I am hesitant in saying this knowing where I am at but it may not be a lack of resources. It may be more of a lack of concentrated effort for what the resources are there for. You know, we have the Title II funding, the Title I funding, all of these NSF funding, all of these resources that could be utilized for systemic reform in math and science and in improving in that realm but many times those are not coordinated in a systemic manner, in a manner in which the goals are common. They go off in different directions.

I think there needs to be a refocus at the national level to make sure that those things are focused on common goals.

And another thing is tapping into the enormous potential that is out there in students. When you look at the gap between minority and non-minority students, many times that is ignored because it is such a negative but all of that gap represents the untapped potential that is out there in our kids that could be taking some of these jobs, and they are very capable of doing it. Just for some reason we haven't gotten there.

Dr. PARRAVANO. Yeah. And I would just like to add a few things. One is that I feel that eventually once the models are proven and up and running and the figures that have been discussed here like 200 million or 500 million are likely not going to be enough, but I would also like to say that I think this Subcommittee could have a very, very important impact on other items in addition to resources. And let me just very briefly mention two of them.

One is—one of them is commitment, and that is not something that money can buy.

Mr. ETHERIDGE. Sustained commitment.

Dr. PARRAVANO. Sustained commitment. And the other one I have actually been reading while I have been here and that is where there is no vision the people perish. That is up there on the wall. Vision is not something that money can buy but vision is something that this country's leaders can certainly instill in all of us.

Mr. ETHERIDGE. Mr. Chairman, thank you for being so generous with your 5 minutes. If I may have one more 30 seconds I would say that——

Chairman SMITH. We will take it out of Mr. Israel's time but that is all right. Go ahead.

Mr. ETHERIDGE. I would say that someone commented earlier as we were talking about youngsters, "I think all young children are scientists." I have seen it at the very early age. They are excited, they are energized, they deal with it, and I think we, all of us, have a challenge in this area to not let it dry up and wane as they move to middle school. I think that is one of our great challenges. Thank you.

Chairman SMITH. And Mr. Etheridge, you know, it is delighted to add additional time. Part of your comments coming out of your

5 minutes certainly are a good testimony with your experience that is helpful as we pursue this. Mr. Israel, for any comments or questions.

Mr. ISRAEL. Thank you, Mr. Chairman. I will be very brief. My question is directed at Dr. Schaffer, although if any of the other panelists would like to add some insights I would appreciate it. I am very intrigued with the Urban Teacher Education Program, and I appreciate the work that is being done. It is an important program in recruiting math and science teachers to under-represented areas but there is a flip side to that equation. Right now 44 percent of America's student population is African-American, Latino, and yet 15 percent of America's teachers are African-American, Latino. Are we doing anything in order to increase the percentage of traditionally underrepresented populations in the classroom as far as teachers, particular math, science teachers?

Dr. SCHAFFER. That is a very good point. And the answer to it is we could do much more than we are. I think the first thing is that actually the recruiting in that particular Urban Teacher Education Program has, although not focused on Baltimore alone, has had a strong focus and an attempt to bring in folks from the local neighborhoods into programs. And I think that is one way that they have tried to encourage people to work actually very much near where they are living and to involve people in the African-American community and Latino community into the teacher education programs and into the science and education programs.

This is also difficult. We have to get people with resources, personal resources, personal capacity in the area of science and mathematics or we have to grow it, and that is the other thing we have been trying to do as well. I think the 2+2+2 Program is another way where you start with high school children or high school students and younger to start talking about it is good to be a scientist, it is good to a mathematician. It is also good to be a teacher of mathematics and science as well. And that is valuable.

It is interesting. Some of you may know who Freeman Hrabowski is. He is the president of University of Maryland Baltimore County, and I have listened to him speak. He is African-American. His interest is in young African-American youth and their involvement in science and mathematics. That is his strength, and he has added now to his talks a statement, how many of you want to become teachers, because I think it is starting to become critical not just to have science and mathematicians but how are we going to get them if we don't have teachers to teach them. And so I think that is that leadership issue, that communication issue is critical in speaking to those crowds.

So 2+2+2 I think is helpful. Getting—working with teachers to start enticing people into our own fields and as teachers and then third, resources in a different way, and I talked about a package. If we are going to move people from being scientists to being teachers of science, how do we get them to make that transition? How do we train them, fund them while they are doing that, and then supporting them once we have got them. I think that is a big area that we need to work on, whether they have been engineers or they have been actuaries or whatever they have been previously.

Dr. SADLER. As a professor of education I have had a lot of African-American and Hispanic students who became teachers and also scientists who became teachers. One of the most disturbing elements about choosing teaching as a profession for someone who has got expertise in science, math, or engineering, is that they earn half as much money as a teacher as they do in the market. And I don't see schools changing in paying teachers more in these fields of math and science. There are a lot of reasons for that which I don't agree with but it doesn't look like that happens in very many places. Perhaps a Federal role would be more loan forgiveness for these students who graduate from a college carrying tens of thousands of dollars in loans. That may be a way for the Federal Government to help subsidize this movement of people with good science and math backgrounds into this profession.

Mr. ISRAEL. Thank you. This is an issue that I know that many people are very interested in, and I look forward to working on it with you as well as the members of the Subcommittee under the leadership of the Chairman and Ranking Member. Thank you, Mr. Chairman.

Chairman SMITH. Mr. Ehlers.

Mr. EHLERS. Thank you, Mr. Chairman, and I thank you for your courtesy. Just a quick comment on the pay issue, I have been advocating throughout this country as I speak that we have to have a pay differential. It makes absolutely no sense in a country which is founded on the principle of free enterprise and is devoted to a market economy to say that this works in every profession except teaching. You are quite right. The pay differential is almost a factor, too, and I don't think you have to pay twice as much because teaching has many attractions, a sense of fulfillment that you don't find and other things. But clearly if you are expecting people at a high rate of pay to come and teach and you want to compete with the market, you have to offer more than existing wages. We do have loan forgiveness already. That doesn't reach everyone because the very poor and the very rich don't have loans. The poor have grants. The rich has parents, and it is only the in-between who get the loans. I have—one of my bills provides a tax credit, which would apply to everyone, and that may be a solution, too, although it is very hard to get tax credits through Ways and Means. But certainly this is something we have to address. Dr. Parravano, I admire the program that you have developed, and the four, I think it is four school districts you have.

Dr. PARRAVANO. Correct.

Mr. EHLERS. Three in New Jersey, one in Pennsylvania.

Dr. PARRAVANO. Correct. Yes.

Mr. EHLERS. And that is excellent. There are other programs that have been developed across the country, either by chemical firms, pharmaceutical firms, by local efforts by national laboratories, and I think they are all admirable. I face two questions in trying to write legislation that will affect the whole nation. First of all, how do we propagate the good ideas and the good programs? Secondly, how do we coordinate these nationally? How do we make teachers aware of them even if they can only be used as a supplementary program as part of another curriculum? And I have come up with an answer but I am not totally happy with it. I would be

very interested in hearing your comments as a group about how we can handle this. We have NASA, we have DOE, we have a corporation such as yourself all producing units of science. How do we coordinate and propagate these——

Dr. PARRAVANO. Uh-huh.

Mr. EHLERS [continuing]. Good programs?

Dr. PARRAVANO. Yeah. Well, I think—let me take those two questions separately. I think that coordination is a very, very difficult issue, and I know that on our scale, that is, that what we have been really trying to do is to work with other like-minded corporations to share some of the lessons that we have learned, to share strategies, but also to really try to coordinate the offerings of our programs so that we really don't try to replicate each other. And to the extent possible we have used infrastructures that are already out there. We have tried not to reinvent the wheel so to speak and to come up with a coordinating council of our own. So for example, we have had the National Science Resources Center, which is located here in Washington, and it is an entity that has been—that is part of the National Academy of Science in the Smithsonian. They have been very, very effective in coordinating corporate efforts in science education. So perhaps highlighting that and encouraging companies to become part of that might be one way of doing it.

I think the other part of your question is how do we encourage other companies to do this. Well, I think, you know, part of our role, and when I say our role, my role at a company like Merck and my counterparts at other companies, we feel very, very strongly, and we spend quite a bit of our time in going out and talking with other companies and other foundations about our strategies, the fact that a long-term commitment, a focused commitment is very, very critical.

So we have been very concerned about getting other companies to commit to the same level that we have, and we are in our own way really trying to deal with that. So I think that your concerns are very good ones, and we would be more than willing to work with you on how to bring these to a greater scale.

Mr. EHLERS. Do you trade ideas with the—with other firms including those in the field as to how you are doing it and how they are doing it and try to come up with——

Dr. PARRAVANO. Oh, absolutely.

Mr. EHLERS [continuing]. Something else?

Dr. PARRAVANO. Every chance we get both formally and informally. And I think that it is important to point out that this is a fairly new way of doing business between businesses because in the past businesses have been fairly protective of how they work in particular areas or in particular partnerships but now we all realize that the problems are far greater than any one of us can solve. And there is also a greater realization of what is working. So why not trade that information? Why not share it?

Mr. EHLERS. Thank you. My time has expired.

Chairman SMITH. It would seem that there is so many spokes to this wheel, and we are trying to improve one of those spokes that make the wheel stronger and more complete because in terms of our ability to make our communities a better place to live, work,

and raise our kids is going to depend partially or significantly on increasing productivity. And productivity as even Alan Greenespan has acknowledged comes from research and the development of that research. And so we are ultimately interested in keeping, encouraging science and math in K through 12 but then some kind of a motivation that is going to allow them to go to school and not take the $50,000 job that a lot of engineers can get with a Bachelor's right now and stay in the field of science in research and that endeavor.

Let us assume for a moment that we are able to come up with excellent types of lesson plans, demonstrations in the early years of school, different grade levels. How do we make it most easy on the—trying to distribute what we have learned and the good things that might add to a teacher's ability to motivate students? How do we disseminate that? Should we have conferences? Should there be some of the great lesson plans and techniques of demonstration that might be on the internet? Briefly a comment from each one of you, maybe starting with Mr. Parravano.

Dr. PARRAVANO. Yeah. I think just one aspect that has been very, very effective. We were fortunate awardees of a National Science Foundation grant, part of their local systemic change grant. And as part of the award we were more than encouraged, we really were required to use National Science Foundation funded instructional materials. These are very, very high quality materials, and we incorporated them into our professional development program and made sure that the teachers had available for them when they went back to school in September the same instructional materials.

So making that connection between the professional development programs and the high quality instructional materials part of a grants program I think was a brilliant stroke.

Mr. GARNER. One thing that we are doing as part of our Urban Systemic Program is trying to establish a network of teachers throughout the State of Oklahoma and hopefully expand from there. Every time that we have the opportunity to get teachers in a room together to share ideas on effective practices, it is overwhelming what the result is because the teachers in isolated areas seem to know effective ways to teach. We don't provide them enough opportunity to share those ideas and work with other teachers, gain new ideas and share the ones that they have.

Another thing going back to the partnerships we have developed good partnerships with Sharp Electronics, who is providing some resources that they have available to them in graphing calculators for math classes. Also Lucent Technologies and the National Science Resource Center have teamed up. We need to have a mechanism in place to get the resources from Merck, Lucent, National Science Resource Center to get them more focused in one direction. It seems like every corporate foundation has their own agenda, and we need to get a more common goal out there or set of goals.

Chairman SMITH. And certainly that is another question. Your success in areas that we can bring business and industry in to participate and help fund some of these efforts because it is in the long run in their best interest but Dr. Schaffer on—maybe on both questions.

Dr. SCHAFFER. Well, the first thing is I think there are a number of very fine materials. Many of them are NSF-funded materials that are very beneficial to teachers. The difficulty is many of them are unaware of those materials and have not had the time really to study them or think about them. Time is really an enemy of the classroom teacher. They are very short in every area. There are significant demands on their time. Finding time for them to sit down, work through, talk through their own ideas and those of very strong programs, be they business programs or university developed programs, I think is a critical piece of this. It is kind of a Cadillac model in a way but to give people that kind of time but to respect them as professionals and their own develop I think has got to be built into a system so that they can explore and they can develop.

A second piece of this is in many ways, and this is not true of National Science Foundation materials, but there are many materials out there in science but there is probably better information on which refrigerator you might buy than on which science program you might use. And I think that is an issue that we have not addressed as well as we could.

Chairman SMITH. Well, and certainly having two daughters that teach and a wife that taught time is pretty crucial and now even more so with so many teachers not only being teachers but counselors and babysitters. It is——

Dr. SCHAFFER. And mentors and many other things.

Chairman SMITH. Dr. Sadler.

Dr. SADLER. Yes. Well, I am committed to a free market approach to dissemination of these quality materials. I know that many teachers learn about these materials when they go to national and regional conferences, and if the Federal Government could subsidize some of these teachers to attend these conferences, that would probably help a lot. They will meet other teachers who use these materials and can learn a lot from that.

Also, we have had lots of teachers on sabbatical at our research center where they work with scientists, usually on some educational problem, and those kinds of sabbaticals we award from our grants but there could be a national program.

In addition, institutes for teachers, we usually run several every summer but to comment on something Dr. Ehlers said earlier about tax credits, one of the added costs of being a science teacher in the United States is that every science teacher I know spends at least $1,000 out of pocket every year at the hardware store or supermarket, Radio Shack to buy materials that don't get into the budget in the—for their school department, for their science department. It would be nice if they could actually get some tax credit for those out-of-pocket expenditures.

Chairman SMITH. We have 3 minutes left on this vote, Veron, so very quickly.

Mr. EHLERS. Okay. Just very quickly. If they would simply get the school to reimburse them and they then contribute the money back to the school, they get a receipt for a tax-deductible contribution. You could also deduct the materials but they might not get credit for it when they—if the IRS audits.

Chairman SMITH. Gentlemen, with your permission we would like to be allowed to send you additional questions that haven't been asked but we have got two more votes ahead of us right now, and so I am going to adjourn this Subcommittee with our thanks for your efforts today. And we will let the record show that the witnesses nodded when—they agreed to answering questions, additional questions by mail. Gentlemen, thank you again, and we will be talking to you. With that the Subcommittee is adjourned.

[Whereupon, at 3:35 p.m., the Subcommittee was adjourned.]

Appendix 1:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses submitted by David Garner, Director, Urban Systemic Program, Oklahoma City Schools, Curriculum and Instruction Department

Question 1:

During the question and answer portion of our hearing, you commented that a lack of resources may not be as problematic as the lack of concentrated effort or a set of common goads for existing resources. Could you provide an example of the difficulties imposed by fragmented resources? Also, could you recommend ways to better align program priorities and goals without creating programs that are so closely aligned that they become duplicative efforts.

Response:

An example of how federal resources are fragmented is the National Science Foundation (NSF) and Eisenhower programs, both of which focus on math and science reforms. As director of an Urban Systemic Program funded by the NSF and former coordinator of Oklahoma City Public Schools' Eisenhower programs, I see many possibilities for collaboration and inclusion among these programs. In many cases, which are evident in the goals of the two programs, these are duplicative efforts and still do not provide adequate resources to support professional development at the level needed. Both of these programs constantly encourage school districts to converge resources provided through each of the two programs.

However, a single program with a single vision of support for math and science teachers is much more realistic and attainable. In addition, although the programs encourage convergence at the district level, that convergence is not evident at the national level where the funding originates.

An example of the impact of duplicative efforts is that they require excess administrative functions at the district and state levels. For instance, states receive funding for Eisenhower professional development for programs at the district and higher education levels; however, both programs focus on training for K–12 math and science teachers, both programs require separate evaluations and data collection, and both require additional clerical tasks at the district, state and higher education levels. In addition, the National Science Foundation programs for professional development require an even greater amount of administrative and clerical responsibilities at the district level. A solution must emphasize a "single" program to focus on math and science teacher support at the K–12 level. This support can and should include partnerships between the K–12 and higher education entities, but must focus on the K–12 level providing continuous professional development opportunities for teachers with a reduction in "bureaucratic" requirements.

The fragmentation of programs and resources is evident in federal funding opportunities. Rather than funding literally hundreds of programs and reform efforts, it would be much more beneficial to focus on a single goal or vision to provide support to teachers who educate the children. A quick glance at the funding opportunities available through the NSF and Department of Education illustrates my point. There are literally hundreds of funding opportunities available, yet very few of them focus on systemic change and teachers at the classroom level. In fact, most focus on political agendas that are non-sustainable and produce little or no results in improved student learning. Improving student learning through training and support of our teachers should be the emphasis of these programs. This involves quality training programs, additional teacher mentors, improving teacher pre-service programs, lesson and curriculum development, and networking opportunities for teachers.

Question 2:

Which are the most important years in the life of a child for stimulating a life-long interest in science? Is there an age at which this interest typically wares and what can be done to maintain student interest in science through adulthood?

Response:

Based on research and professional experiences I have found that science, not unlike reading and mathematics, is found stimulating to children at a very young age. In fact, at birth a child begins the first steps of scientific discovery when he or she is constantly utilizing the senses to relate to the world surrounding him. The younger the child, especially those vital pre-kindergarten years, the easier it is to stimulate the child's interests and learning abilities.

The stimulated interest in science is much easier to attain at the early childhood levels. However, this stimulus is possible at later grade levels if the child experiences a high quality science learning experience. Thus, the key to attaining and sus-

taining student interest in science is the quality of the science program throughout the Pre–K–12 experience. This "quality" program must include challenging discovery, inquiry, in-depth content, and hands-on experiences at *every* grade level. It is this type of quality instruction that gains the students' interest in the subject and it's when the child experiences the "lecture/text" approach to science instruction that interest wanes. Therefore, national science reform efforts must have a systemic focus and provide service for all students, all teachers, and at all grade levels.

Unfortunately, the concern about when children are motivated through science education is not addressed when many other education decisions are considered. For instance, we know that the early childhood and primary levels are prime opportunities for gaining student interests in science, however decisions are being made at national and state levels which de-emphasize science in our elementary programs. Primarily, the focus at these crucial levels is on reading and math due to testing programs that only test math and reading, and the lack of funding opportunities to support true systemic reform in science throughout the K–12 experience. This in no way should imply that math and reading are not critical subject areas but that science must be equally emphasized as an integrated approach for applying the reading and math skills to solve problems, analyze everyday experiences to make quality decisions, and master reasoning skills.

To further emphasize this point, I recommend the committee consider the impact of many state testing programs in which science is not emphasized at the elementary level. In these states, such as Oklahoma and others, science education is placed on the back burner and that crucial window of opportunity to gain student interest is reduced or eliminated. Evidence of this trend is constantly observed in review of how much time is allocated for science instruction at the elementary level compared to time allocated for math and reading.

In closing, I appreciate the opportunity this committee has provided for me to have input into these very important decisions and ask that you contact me if any clarification or further information is needed. As I follow the education decisions being made at the national level I become very concerned that many of these decisions are being considered in isolation from each other, when, in fact, all of the federal education programs should be aligned and/or combined to better serve the schools. Successful programs, such as the NSF's Urban Systemic Program, are being eliminated while others that have had insignificant impact on student learning are being considered for continued funding. I urge this committee and Congress to carefully review and align all programs to focus on student learning and sustainable systemic change for all children.

ANSWERS TO POST-HEARING QUESTIONS

Responses submitted by Dr. Carl Parravano, Executive Director, Merck Institute for Science Education

Questions Submitted by Chairman Nick Smith

1. In your testimony, you listed key elements to the success of your program including long-term commitment, a sharp and unwavering focus, an emphasis on building capacity, and the constant attention to evaluation and benchmarking of results. Could you provide a more detailed explanation of the way in which your program has built increased capacity?

From its inception, the Merck Institute has taken an activist and systemic approach to the reform of science instruction, going far beyond the provision of funds, volunteers, and materials, to develop the capacity of its partner school districts to support implementation of good instructional practice and high academic standards. The Institute has helped its partners review and purchase new instructional materials for science. It has provided high-quality professional development and technical assistance. It has worked with partner districts to align school and district policies governing curriculum, assessment, professional development, accountability, and resource allocation.

In addition to the work at the district level, MISE has actively sought to create a more supportive environment for the work with its partner districts, by participating in the development of state standards and curriculum frameworks, engaging in public outreach, and networking with other business-school partnerships, thereby broadening the base for reform.

MISE has also encouraged its partner districts to think strategically about their science programs by asking each district to prepare an annual action plan describing their efforts to improve K–8 science education. MISE programs including professional development, as well as committees addressing specific issues such as assessment, have provided the opportunity for teachers within the districts to take on leadership roles and develop expertise in specific areas.

The instructional materials and review process, ability to provide professional development, realigned policies and frameworks, broadened base for reform, strategic focus, and leadership abilities are now integral parts of the districts involved and they contribute to the increased local capacity to improve science education.

Could you share information on the benchmarks by which you evaluate the success of your programs?

MISE charges the Consortium for Policy Research in Education (CPRE) with the task of evaluating its programs by using measurable objectives and providing continuous, formative feedback. CPRE was asked to document MISE's efforts, struggles, and successes beginning in 1992 and publishes its findings in an annual report.

CPRE collects both qualitative and quantitative data to track changes in science education in the four districts. Special emphasis has been placed on how the partnership with MISE has evolved, how successful it has been in stimulating reforms, the degree to which it has enhanced local capacity to improve science education in the four districts, and the extent of improvements in student achievement and participation in science.

Nine sets of questions were framed that address the following topics:

1. Partnerships: the extent of agreement in shared notions and expectations for the partnership
2. Vision: the extent of agreement on what is "good" science education
3. Capacity: change over time and factors influencing capacity
4. Professional Development: needs, opportunities, and quality
5. Pedagogy: what changes take place, how it is affected by policy
6. Student Effects: attitudes, interest, and achievement in science
7. Program and Policy: what changes are made and success in implementation of changes
8. Context: surrounding environment's effect on the partnership, priorities and changes
9. Parent and Community Support: science education as a priority, material investments

CPRE uses a variety of data sources to conduct its work. These include interviews with classroom teachers, and school and district administrators; observations of

classroom lessons; surveys of the entire population of science and math teachers and school principals; observations of partnership professional development activities; attendance at partnership meetings and functions; and interviews with MISE staff.

Specific evaluation tools are used for the more quantitative data collection. Classroom evaluation, for example, is based upon the classroom observation protocols provided as part of the National Science Foundation's Local Systemic Change (LSC) initiative. Observers have strong subject-matter content experience and undergo classroom observation training. Partnership-wide surveys are developed by Horizon Research as part of the national evaluation of the LSC initiative. Student effects are measured using state assessment data from New Jersey, the Stanford 9 achievement test for all 5th and 7th grade students, and course enrollment and participation in upper-level courses at the high school level. Evidence of policy changes and strategic planning is also collected via a document review. Thus, each area that is being reviewed has a distinct procedure for evaluation and a tool that compares the current status to the past history in that area, and also to the status of that aspect in other districts, in the state, and/or in the nation as a whole.

2. Which are the most important years in the life of a child for stimulating a lifelong interest in science?

It is quite difficult to pinpoint the exact age at which a child's interest in science originates or at what age that interest becomes a lasting part of a child's life. However, research suggests that even in early childhood, ages 3 to 5, children are capable of some form of scientific thinking—asking questions with their natural curiosity, formulating hypotheses, observing the world around them, and forming conclusions. The results of one study suggest "that the perception of science as an appropriate or inappropriate field of study is developed before the age of nine."

Is there an age at which this interest typically wanes?

According to the Third International Mathematics and Science Study (TIMSS), test scores confirm that American middle school students perform above average in science, but their performance decreases dramatically by the time they graduate high school. While test scores do not necessarily directly indicate interest in science, it is clear that somewhere during the junior high and high school years, student interest in science decreases as well. The causal relationship between interest and achievement is still unclear.

What can be done to maintain student interest in science through adulthood?

While no single method can be used to maintain this interest, a variety of factors seem to increase science participation and enthusiasm. During early childhood, both formal and informal science experiences have been shown to increase the likelihood that students will be attracted to science courses in the future. During the elementary and junior high years, parental involvement, quality teachers with high enthusiasm for science, science competitions, and informal science experiences such as museums, can all help to increase interest. In high school and college, high quality teachers and instructors, competitions, and scholarships may maintain student interest. And at all levels a student's self-efficacy in science will have a great affect on student interest and participation.

Questions Submitted by Chairman Vernon Ehlers

1. If you were developing a program to spend $200 million per year to improve the nation's elementary and secondary science programs, how would you spend the money?

Middle school science and mathematics are two areas that are in great need of improvement. Large numbers of teachers in these areas are inadequately prepared for their positions due to a lack of content knowledge. It would be worthwhile to offer sabbaticals for educators to obtain a master's degree in related content fields in exchange for a commitment to teach in a middle school for 5 years. This would not only increase the quality of teaching, but would also address attrition at the middle school level, which is a serious problem in urban schools. If half-salary sabbaticals were offered (assuming school districts would pick up the other half), then 5,000 sabbaticals would cost approximately $200 million. If this were done for 5 years, 25,000 additional well-trained educators would be added to the teaching force in a critical area.

What if you could spend $500 million instead of $200 million?

It might also be worthwhile to consider state grants that would enable institutions of higher education to develop graduate level courses that would focus on the math and science content included in the curriculum of the public schools. Currently

it is difficult for teachers who lack this content background to find appropriate courses at universities—especially courses in mathematics. There are few incentives for institutions or faculty to develop such courses. This could be a $50–100 million investment.

Funds could also go towards the creation and support of state incentive programs encouraging undergraduates to pursue teaching careers in mathematics and science. These programs might range from scholarships to loans.

There is an obvious need for stable sources of professional development in all of the states. Matching grants for the development and operation of professional development initiatives in mathematics and science would be an appropriate use of funds. This suggestion could easily use all available funds.

Since assessment drives so much of the curriculum, investing in better state science assessments and developing banks of performance assessment items that the states and/or local districts could tap into would be a worthwhile expenditure. This initiative might use $50–$100 million.

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